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UNIVERSITY OF MONTANA BULLETIN

BUREAU OF MINES AND METALLURGY SERIES NO. 1

THE MONTANA STATE BUREAU OF MINES AND METALLURGY

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STATE SCHOOL OF MINES
BUTTE, MONTANA
MAY, 1919

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STATE BUREAU OF MINES AND METALLURGY STAFF

CLAPP, CHARLES H. - - - - - - - Director and Geology
PhD., Massachusetts Institute of Technology, 1910

ADAMI, ARTHUR E. - - - - - - - - - Mining Engineer
E. M., Montana State School of Mines, 1907

PULSIFER, H. B. - - - - - - - - - Metallurgy and Safety
B. S., Massachusetts Institute of Technology, 1903;
Ch.E., Armour Institute of Technology, 1915;
M. S., University of Chicago, 1918.

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FOREWORD

The purpose of this Bulletin is to call attention to the fact that the Legislative Assembly of the State of Montana, for the year 1919, established in the State School of Mines of the University of Montana a State Bureau of Mines and Metallurgy. The Bureau was established to aid in the development of the mineral resources of Montana. In much the same way that the Agricultural Experiment Station at Bozeman has furthered the agricultural industry of the State, the Bureau of Mines and Metallurgy will stand ready to assist and promote the mineral industry. The Bureau has been established primarily for service, and, as far as is reasonable, those interested may avail themselves of its services free of charge.

CREATION OF BUREAU AND APPROPRIATION

The bill creating the Montana State Bureau of Mines and Metallurgy, enacted by the Legislative Assembly of Montana for 1919 (Chapter 161, page 311), was introduced by Representative Arthur V. Corry, a Mining Engineer of Butte. The Bureau was established as a department of the State School of Mines of the University of Montana, and is under the direction of the State Board of Education, which appoints the director. The regular and special reports of the Bureau are to be printed and distributed as the State Board of Education may direct, and as the interests of the State and of science and industry may demand. All materials collected, after having served the purposes of the Bureau, are to be deposited either in State museums or in the collections of the State School of Mines, and duplicates of representative material are to be distributed to the various educational institutions of the State, so as to be of the greatest educational advantage.

A fund of $20,000.00, necessary for the maintenance of the Bureau, was appropriated for the biennium ending February 28, 1921.

OBJECT AND DUTIES

The Bureau was established primarily for the purpose of promoting the development of the mineral resources of the State, and of increasing the safety and efficiency of mining and its allied operations. A bureau is the best medium for collecting information concerning the mineral resources and industry, and of disseminating such information by answering inquiries and by the publication of bulletins. It is also an efficient agent in the practical solution of the problems of conservation.

Conservation is now taken by most practical men to mean: "Utilization, with a maximum efficiency and a minimum waste." This definition applies particularly to conservation in the mining industry, for, unlike agricultural products, which are annually replenished, the product of the mines consists of only one crop, which must meet the future, as well as the present needs.

To conserve their mineral reserves, large organizations are forced by the stress of circumstances to mine, mill, and smelt their ores efficiently, and to conserve the services and lives of their employees they are forced to mine, mill, and smelt their ores safely. Individuals and companies operating small mines and prospects, of which there are several hundred within the State, do not fail to appreciate the need for efficient and safe operation, but can rarely give to these matters the attention and money necessary to achieve the best results. To assist these men by helping them mine more profitably, under

safer and more healthful conditions, will be a great factor in conservation.

The object and duties of the Bureau, as specified by law, are as follows:

1. To collect, to compile, and to publish statistics, relative to Montana geology, mining, milling, and metallurgy.

2. To collect typical geological and mineral specimens and samples of products; to collect photographs, models, and drawings of appliances used in the mines, mills, and smelters of Montana.

3. To collect a library and a bibliography of literature pertaining to or useful for the progress of geology, mining, milling, and smelting in Montana.

4. To study the geological formations of the State with special reference to their economic mineral resources, both metallic and nonmetallic.

5. To examine the topography and physical features of the State with reference to their practical bearing upon the occupation of the people.

6. To study the mining, milling, and smelting operations carried on in the State, with special reference to their improvement.

7. To prepare and to publish bulletins and reports, with necessary illustrations and maps, which shall embrace both a general and a detailed description of the natural resources and geology, mines, mills, and reduction plants of the State.

8. To make qualitative examinations of rocks and mineral samples.

9. To consider such other scientific and economic problems as in the judgment of the State Board of Education are of value to the people of the State.

10. To communicate special information on Montana geology, mining, and metallurgy.

11. To co-operate with the other departments of the University of Montana, with the State Mine Inspector, and with other departments of the State Government as may be mutually beneficial; and to co-operate with the United States Geological Survey and with the United States Bureau of Mines, in accordance with the regulations of those institutions.

It might be wondered by some, why the Bureau should not undertake to make assays and chemical quantitative analyses free of charge. These matters, however, naturally fall to the private assayer and chemist, for the State should not enter into competition with the legitimate private business of its citizens. However, qualitative tests of samples can be made and many questions concerning the commercial value of the samples may be answered. Samples, ores, and other consignments should be shipped to the State Bureau of Mines and Metallurgy, Butte, Montana, preferably by parcel post, except in the case of large consignments.

ORGANIZATION

The Bureau is organized into four major departments—Administrative, Geology, Mining, and Metallurgy and Safety. The Administrative Department directs the work of the Bureau, sees that requests for information are referred to the proper departments for answer, supervises the co-operative work, oversees the printing, publication, and distribution of the reports of the Bureau, and prepares for the State Board of Education the biennial report to the Legislative Assembly.

The Geological Department undertakes the study of the geological formations and mineral resources of the State, collects geological and mineral specimens, makes qualitative examinations of rocks and mineral samples, and prepares geological reports.

The Mining Department makes the necessary surveys and prepares topographic and other base maps, studies the mining operations of the State, and prepares reports on mining operations.

The Metallurgical and Safety Department collects statistics with regard to the mineral industry of the State, studies the milling and smelting operations, engages in metallurgical research, and prepares reports on metallurgy and safety.

PLAN OF WORK

Work for which there is special and immediate demand will receive first attention, and that which is planned for the biennium 1919-1921 consists of the preparation of a report on the Mining Districts of Montana, giving location of districts, accessibility, valuable products, statistics of production, summary of geological features, and a bibliography of available maps and literature; and the preparation of reports on the various mineral products of current interest, such as oil and gas, gypsum, and road-building material.

The Mining Department is undertaking the preparation of a report on mining methods and timbering for prospects and small mines.

Besides collecting statistics on the mineral resources of the State, the Metallurgical and Safety Department will study conditions of safety, welfare, and hygiene in the appropriate industries and will prepare circulars on the advance of this phase of industry in other communities. It will also undertake to standardize small shipments of mineral products and ores; engage in research in the structure of copper and other metals, with a view of determining the relation of the structure of metals to the physical properties; and will prepare bulletins on the theory and application of flotation and the ball mill to small mining properties, and on the cyanide process as used in Montana.

Application has been made to the United States Geological Survey and United States Bureau of Mines to engage in co-operative work with the State Bureau. Much good should result from the proposed co-operation, for similar co-operation has been proved, in certain parts

of the United States, to be very successful and beneficial. Attention will also be drawn to the desirability of securing a United States Bureau of Mines Experiment Station in Butte.

PUBLICATIONS

The results of the work of the bureau will be made accessible to the public by the publication of bulletins and circulars. These will be sent free of charge to those requesting them. The publication of pertinent material through local co-operation with mining companies, chambers of commerce, and newspapers should be of direct and immediate benefit to the people of the State.

The demand for individual correspondence, such as heretofore has been carried on by the School of Mines, and which grew to such volume as to interfere with the regular work of the school, was one important factor leading to the establishment of the Bureau, and a large part of the work of the Bureau will consist in carrying on such correspondence in a more satisfactory way than has heretofore been possible.

HOW TO USE THE BUREAU

The Montana State Bureau of Mines and Metallurgy has been established for the use of anyone interested in the mining industry of Montana. Its success will depend largely upon how much service it is asked to give. The Bureau is accessible to all, and is located at the State School of Mines, in Butte. If possible, bring your problems to the Bureau in person; if not, send in your samples and questions by mail or express. All samples and letters should be addressed to the State Bureau of Mines and Metallurgy, Butte, Montana.

The Bureau is reliable and is well equipped to carry on many different kinds of investigations. So far as is reasonable, consistent with reputable practice, and within the limits of the available funds, all problems and questions will receive careful consideration. Ask for the reports and maps of the Bureau, and use them. Do not go ahead without obtaining the available information concerning the mineral resources of Montana. Let the Bureau help you develop the mineral resources and increase the safety and surety of the mining industry.

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UNIVERSITY OF MONTANA BULLETIN
BUREAU OF MINES AND METALLURGY SERIES NO. 2

THE MONTANA STATE BUREAU OF MINES AND METALLURGY

DIRECTORY MONTANA METAL AND COAL MINES

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M. S., University of Chicago, 1918.

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no. 2

FOREWORD

The purpose of this bulletin is to serve as a directory of all the metal and coal mining companies in the State of Montana. Although every effort possible by correspondence was made in the attempt to get information on every mining company in Montana, it is possible that some companies have been overlooked. However, it is believed that this bulletin contains the names of most of the operating companies of the State, together with some general information on each company, and that the bulletin will serve as a valuable reference book for those interested in the mining industry. This bulletin is supplementary to a report on the various mining districts of Montana which is now being prepared by the Geological Department of the State Bureau of Mines and Metallurgy.

DIRECTORY OF MONTANA OPERATING METAL MINES

ALICE GOLD AND SILVER MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., John D. Ryan; Secy-Treas., D. B. Hennessy, 42 Broadway, New York, N. Y.
Operating Dept.: Gen. Mgr., John Gillie, Butte; Asst. Mgr., W. B. Daly, Butte; Genl. Supt., C. L. Berrien, Butte.
250 H. P. Steam and 150 H. P. Electric.
No. of men employed: 125.
Ores: Complex sulphides of silver, zinc, lead.
Daily output: 250 tons.
Output for 1918: 32,600 tons.
Miscellaneous Information: Property has been closed down most of the year 1919 on account of poor zinc market.

ALTA MONTANA MINING CO. **Corbin.**

Location: Colorado Mining District, Jefferson County.
Officers: Mgr., Raymond Guyer, 218 Symons Bldg., Spokane, Wash.
Operating Dept.: Supt., R. E. Snow, Corbin, Mont.
150 H. P. Electric.
No. of men employed: 12.
Ores: Lead-Silver.
Miscellaneous Information: Past two years has been spent in opening up and dewatering old works, which work is now about complete. A small amount of ore was taken out in the year 1918 by leasers.

AMERICAN GEM MINING SYNDICATE. **Philipsburg.**

Location: Flint Creek Mining District, Granite County.
Officers: Pres., L. M. Rumsey; Vice-Pres., C. G. Ewing; Treas., L. S. Mitchell; all 408 Olive St., St. Louis, Mo.
Operating Dept.: Gen'l Mgr., C. G. Ewing, Philipsburg.
Water power.
No. of men employed: 30.
Ores: Sapphire placer.

ANACONDA COPPER MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., C. F. Kelley; Vice-Pres., B. B. Thayer; Secy. and Treas., A. H. Melin; Gen. Auditor, J. T. Roberts; Asst. Treas., D. B. Hennessy; all 42 Broadway, New York; Asst. Secy., R. D. Cole, Butte.

Operating Dept.; Mgr. of Mines, John Gillie; Asst. Mgr. of Mines, W. B. Daly; Gen. Supt. of Mines, C. L. Berrien; Asst. Gen. Supt. of Mines, E. M. Noriss, J. J. Carrigan, and J. P. O'Neil; Chief Geologist, Reno H. Sales.
Electric, Steam, and Compressed Air.
No. men employed: 9,000 to 11,000 (normally).
Principal ores: Copper, silver, gold, zinc, and manganese.
Daily output: 15,000 tons.
1918 output: 4,925,022 tons.

Miscellaneous Information: This company owns 1,168 acres of mineral claims at Butte, including all the property formerly held by the following companies: Boston & Mont., Cons. C. & S. Mng. Co.; Butte & Boston Cons. Mng. Co.; Red Metal Mng. Co.; Washoe Copper Co.; Parrot Silver and Copper Co.; Trenton (formerly Colorado) Mng. & Dev. Co.; Big Blackfoot Lumber Co.; Diamond Coal & Coke Co.; Original Cons. Mng. Co.; Colusa Parrot Mng. & Sm. Co. This property includes the following mines and departments:

Anaconda Group.

Badger State	Moonlight	Bell-Diamond
High Ore	Mountain Con	Anaconda
Never Sweat	Original	Steward
St. Lawrence	Gray Rock	Belmont

Boston & Montana Group.

Mountain View	Pennsylvania	West Colusa
Tramway	Leonard	Berkeley
Silver Bow	Tropic	

Zinc Group of Mines

Poulin	Nettie	Bonanza
Emma	Alice	Lexington

This Company also operates a gold property at Southern Cross, fifteen miles west of Anaconda.

Reduction Departments.

Washoe Reduction Works, Anaconda.
Frederick Laist, Manager.
L. V. Bender, Gen. Supt.
Boston & Montana Reduction Works, Great Falls.
James O'Grady, Manager.
A. E. Wiggin, Supt.

Coal Department.

F. W. C. Whyte, Manager, Anaconda.
Thos. Snedden, Supt., Diamond Coal & Coke Co., Diamondville, Wyoming.
Thos. Good, Supt., A. C. M. Co., Coal Dept., Washoe.
C. A. Sederholm, Supt., A. C. M. Co., Coal Dept., Sand Coulee.

Lumber Department.

Kenneth Ross, Manager, Missoula.
M. M. Ross, Supt., St. Regis.

ALLIANCE COPPER COMPANY. Butte.

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., Donald Campbell, Butte; Vice-Pres. and Treas., J. D. Slemons, Butte; Sec'y., A. T. Morgan, Butte.
Mine not operating.

AMERICAN SMELTING AND REFINING CO. East Helena.

Location: Lewis and Clark County.
Officers: Pres., S. Guggenheim; Sec'y, W. E. Merriss; both at 120 Broadway, New York, N. Y.
Operating Dept.: Mgr., C. W. Adams, East Helena; Supt., R. L. Strobel, East Helena.
780 H. P. Electric.
No. of men employed: 300 to 400.
Ores smelted: Gold, silver, and lead.
Daily output: 75 tons lead.
1918 output: 27,564 tons lead.

ANGELICA MINING & DEVELOPMENT CO. Wickes.

Location: Colorado Mining District, Jefferson County.
Officers: Pres., C M. d'Autremont, Wickes; Vice-Pres., Chas. D. Horton, Wickes; Sec'y-Treas., C. K. Tibbetts, Helena.
Operating Dept.: Mgr., C. M. d'Autremont, Wickes; Supt., Chas. D. Horton, Wickes.
60 H. P. Electric.
No. men employed: 50 to 55.
Ores: Gold, silver, lead, copper, and zinc sulphides.
Daily output: 50 tons.
1918 output: 12,583 tons.
Miscellaneous Information: Developed by shaft 800 feet deep and adit tunnel 4,500 feet in length connecting with shaft. Lead carbonate ore to 400 feet, sulphide zinc-lead ore, with some copper, to 800 feet. Ore shoots 100 to 300 feet in length, 3 to 20 feet wide. Six patented claims, 109 acres. Both shipping and concentrating ore being developed.

BALD BUTTE MINING & MILLING CO. Marysville.

Location: Bald Butte Mining District, Lewis and Clark County.
Officers: Pres., W. A. Stone, Boston, Mass.; Sec'y-Treas., Wm. M. Belcher, Boston, Mass.
Operating Dept.: Supt., Geo. W. Padbury, Marysville.
35 H. P. Electric.
No. men employed: None at present.
Daily output: None.
1918 output: 760 tons from lessees.

BALKAN BUTTE COPPER MINING CO. Elk Park.

Location: Elk Park Mining District, Jefferson County.
Officers: Pres., Chas. Steele, Butte; Sec'y and Treas., T. Tomich, Butte.
Operating Dept.: Gen. Mgr., Chas. Steele, Butte; Mgr., T. Tomich, Butte.
Not operating at present.

BARNES-KING DEVELOPMENT CO. Kendall.

Location: North Moccasin Mining District, Fergus County.
Officers: Pres., C. W. Goodale, Butte; Vice-Pres., A. J. Davis,

Butte; Sec'y., John E. Corette, Butte; Treas., C. C. Swinborne, Butte.
Operating Dept.: Gen. Mgr., Geo. T. McGee, Helena.
Electric power.
No. of men employed: 90.
Ores: Gold and silver.
Daily output: 100 tons.
Miscellaneous Information: Also owns and operates the Shannon Mine and the Piegan-Gloster Mine and Mill, both at Marysville, Montana.

BASIN MINING CO. **Philipsburg**

Location: Flint Creek Mining District, Granite County.
Officers: Pres., L. W. Rumsey, Jr., 408 Olive St., St. Louis, Mo.; Vice-Pres., C. G. Ewing, Philipsburg; Treas., L. S. Mitchell, 408 Olive St., St. Louis, Mo.
Operating Dept.: Gen'l Mgr., C. G. Ewing, Philipsburg.
Water power.
No. men employed: 15.
Ores: Gold placer.

BEAVER CREEK MINING CO. **Zortman**

Location: Little Rockies Mining District, Philips County.
Officers: Pres., Chas. Whitcomb, Helena; Sec'y, Notley Thompson, Helena.
Ores: Gold.
Miscellaneous Information: 150,000 tons of ore blocked out, but present conditions are unfavorable to operation.

BEN HUR MINING CO., LTD. **Saltese.**

Location: Denemora Mining District, Mineral County.
Officers: Pres., D. S. Dickson, Quartz; Vice-Pres., Frank Bell, Saltese; Sec'y., Chas. J. Luedke, Saltese; Treas., Chas. A. Keating, Wallace, Idaho.
Not operating at present.

BLUE BIRD MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Treas., Clarence W. McGuire, 89 State St., Boston, Massachusetts.
Not operating at present.

BLUE VEIN COPPER MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., F. L. Melcher, Butte; Vice-Pres., J. F. Charles, Butte; Sec'y., Lewis A. Smith, Butte.
Has not been operating for ten years. Owns following claims: Blue Vein, Blue Vein No. 2, Ozone, Myrahl, North Star, Little Boulder, Bunker Hill, Valentine, and Columbia.

BONANZA BUTTE MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., John Kenoffel, 17 S. Main St., Butte; Sec'y-Treas., W. R. Youlden, N. Main St., Butte.
Ores: Silver, lead, copper.

BOSTON-BUTTE COPPER & ZINC CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., W. W. McDowell, 46 E. Broadway, Butte; Sec'y-Treas., W. E. Reynolds, 46 E. Broadway, Butte; Vice-Pres., F. J. Dorhofer, Butte.
Property has never been developed and is not operating.

BROADWATER COUNTY MINING CO. **Townsend.**

Location: Park Mining District, Broadwater County.
Officers: Pres., James J. Fisher, Townsend.
Miscellaneous Information: Short of funds and, therefore, not doing any mining at present.

BUTTE BACORN COPPER CO. **Butte**

Location: Summit Valley Mining District, Silver Bow County.
This company was absorbed by the Great Butte Copper Co., which see.

BUTTE COPPER CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., James H. Rowe, Butte; Vice-Pres., E. F. Lawlor, Boston, Mass.; Sec'y, W. M. Hanson, Butte.
Operating Dept.: Supt., E. L. Ralston, Butte.
275 H. P. Electric.
No. men employed: 40.
Ores: Silver, gold, zinc, and lead.
Daily output: None.
1918 output: 1,760 tons.
Miscellaneous Information: Development work only being done in 1919. Mine being operated by Anselmo Mining Co.

BUTTE COPPER CZAR MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., C. F. Murphy, Anaconda; Treas., John K. Claxton, Butte; Sec'y, L. P. Sanders, Butte.
Operating Dept.; Gen. Mgr., E. C. Meiklejohn, Butte.
Electric power.
No. men employed: 20.
Ores: Copper.
Miscellaneous Information: This mine has not been operated since July, 1918, but plans are being made to reopen work and operations within the next ninety days.

BUTTE COPPER KING MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., Chas E. Beebe, Butte; Sec'y-Treas., A. P. Henningsen, Portland, Ore.
This company owns property consisting of three undeveloped claims located north of the Butte Water Company's Reservoir in Butte.

BUTTE COPPER & ZINC CO. **Polaris.**

Location: Polaris Mining District, Beaverhead County.
Officers: Pres., A. J. Seligman, 61 Broadway, New York; Sec'y-Treas., D. J. Fagensen, 61 Broadway, New York.
Operating Dept.: Gen. Mgr., Glenn Anderson, 46 E. Broadway, Butte.
200 H. P. Steam.
Ores: Silver and copper.

BUTTE & GREAT FALLS MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., E. Bryant Crump, Lexington, Ky.; Sec'y-Treas., Allen Pierse, Great Falls.
Operating Dept.: Gen. Mgr., R. M. Green, Butte.
Electric Power.
No. men employed: 20.
Ores: Copper and silver.
Miscellaneous Information: This mine has not operated in the past two years, but a plan for refinancing same is now under way. Efforts are being made to induce Eastern capital to finance further development work at the mine. The prospects are good for an early reopening of development work. Mr. R. M. Green, the General Manager, above mentioned, died some time ago and his place remains vacant. It will be filled at an early date, as soon as financial arrangements are completed.

BUTTE HILL COPPER MINING CO. **Walkerville.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., Maurice Essenberg, New York, N. Y.; Sec'y-Treas., H. A. Frank, Butte.
Not operating at present.

BUTTE & LONDON COPPER DEVELOPMENT CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., W. W. McDowell, Butte; Vice-Pres., John D. Haines, Butte; Sec'y., W. E. Reynolds, Butte; Treas., E. S. Passmore, Butte.
Property has been closed down for three years.

BUTTE MAIN RANGE COPPER MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
This property, consisting of 38 acres, was sold to the Tuolumne Copper Mining Company in 1918.

BUTTE-MILWAUKEE MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
This property, which is under control of the Butte & Superior Mining Company, was never a producer, and has been closed down for several years.

BUTTE-NEW YORK COPPER CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
This property is controlled by the Butte & Superior Mining Company, but no operations have been conducted for several years.

BUTTE & SUPERIOR MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., D. C. Jackling; Sec'y, A. J. Ronazhan; Treas., C. W. Peters; all 25 Broad St., New York.
Operating Dept.: Gen. Mgr., J. L. Bruce, Butte; Asst. Mgr., Chas. Bocking, Butte; Mine Supt., A. B. McLeod, Butte; Mill Supt., E. V. Daveler, Butte.
7,500 H. P. steam, electric, and compressed air.
No. men employed: 1,200 daily.
Ores: Zinc, lead, silver.
Daily Output: 1,400 tons.
1918 output: 469,079 tons.

BUTTE & VIPOND GOLD MINING & MILLING CO. **Melrose.**

Location: Vipond Mining District, 16 miles northwest of Melrose, in Beaverhead County.
Officers: Pres., James M. Hinkle, Butte; Vice-Pres., Thos P. Manley, Butte; Treas., William Worth, Butte; Sec'y, W. E. Carroll, Butte.
Miscellaneous Information: This property, which is a gold, silver, lead property, is developed by a 740-foot tunnel tapping a vertical shaft at 200 feet. Work of draining was finished in 1919. The property consists of five claims, formerly known as "Queen of the Hills," but now known as "Martin," "Jenkins," "Shady," "Little Victor," and "Vipond Park" Lodes. Not operating at present.

BUTTE & WILLOW CREEK MINING CO. **Pony.**

Location: Mineral Hill Mining District, 4 miles from Pony, in Madison County.
Officers: Pres., P. T. McDermott, Helena; Vice-Pres., James E. Redmond, Butte; Sec'y., James Naughten, Butte.
50 H. P. water and steam.
Ores: Iron pyrites, gold and silver.
Not operating since 1914.

CAPE NOME COPPER MINING CO. **Clinton.**

Location: Wallace Mining District, Missoula County.

Officers: Pres., E. Donlan, Missoula; Sec'y-Treas., H. T. Wilkinson, Missoula.
120 H. P. Steam—two 60 H. P. boilers.
Ores: Copper and silver.
Miscellaneous Information: This property has 4,600 feet of development work, including a double compartment shaft 500 feet deep, with drifts on the 100, 300 and 500-foot levels. Property not operating at present.

CASCADE SILVER MINES AND MILLS. **Neihart.**

Location: Montana Mining District, Cascade County.
Officers: Pres., Geo. H. Brabrook, Neihart; Vice-Pres., Lowndes Maury, Butte; Sec'y., Wm. R. McLure, Philipsburg; Treas., W. P. Wren, Great Falls.
Operating Dept.: Gen Mgr., Geo. Hale Brabrook, Neihart; Supt., Thos. Westgard, Neihart.
Electric power.
No. men employed: 200.
Ores: Silver.
Daily output: 200 tons.
1918 output: 2,500 tons.

COLUSA LEONARD EXTENSION COPPER CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
This property, consisting of 42 acres, was sold to the Tuolumne Copper Mining Company in 1918.

COLUSA-PARROT MINING & SMELTING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., W. A. Clark, Butte; Vice-Pres., W. C. Siderfin, Butte; Sec'y, W. C. Messias, Butte.
25 H. P. Electric.
No. men employed: 20.
Daily output: 1,300 tons.
1918 output: 387,073 dry tons.
Ores: Working copper tailings at Butte Reduction Works, Butte.
Miscellaneous Information: Tailings are shipped to Timber Butte Milling Co. for concentrating, and concentrates shipped to Anaconda Copper Mining Company's Smelter, Anaconda.

COMBINATION OPERATING COMPANY. **Philipsburg.**

Location: Flint Creek Mining District, Granite County.
Officers: Company not organized at this date and officers not officially appointed. However, Geo. C. Crangle, Ray E. Tower, Edward Roach, Harry T. Lewis, Marcus L. Hurley are the owners and operators.
60 H. P. Steam.
No. men employed: At present, about ten engaged in remodeling mill. Operating force will be about 25.
Ores: Silver and copper (subordinate: lead and gold).
Daily output: 100 tons.
1918 output: None.
Miscellaneous Information: Remodeling chloridizing and leaching plant to treat old mill tailings.

CONREY PLACER MINING CO. **Ruby.**

Location: Pres., Chas. F. Adams, Boston, Mass.; Vice-Pres. and Consulting Engineer, Hennen Jennings, Washington, D. C.; Sec'y and Treas., F. F. Stanley, Boston, Mass.
Operating Dept.: Business Mgr., G. H. Edmunds, Ruby; Dredge Supt., O. O. Sweeny, Ruby.
1,475 H. P. Electric.
No. men employed: 55 (average).
Ores: Placer gold and silver.
Daily output: 15,000 cu. yds.
1918 output: 3,350,000 cu. yds.
Miscellaneous Information: No. 1 dredge operated full year with 7½ cu. ft. buckets; No. 2 dredge operated 4 months with 7½ cu. ft. buckets, and No. 4 dredge operated full year with 17 cu. ft. buckets.

CRYSTAL COPPER COMPANY. **Butte and Basin.**

Location: Summit Valley Mining District, Silver Bow County; Cataract Mining District, Jefferson County.
Officers: Pres., B. S. Parker, 31 Milk St., Boston, Mass.; Sec'y, Eugene H. Walker, 31 Milk St., Boston, Mass.
Operating Dept.: Gen. Mgr., Goldsmith Mine, Butte, W. D. Gibson, Butte; Mgr. and Lessee, Crystal Mine, Basin, A. C. Ray, Basin.
100 H. P. Electric.
Ores: Crystal Mine, Basin, copper and silver; Goldsmith Mine, Butte, silver and gold.
Miscellaneous Information: Both these mines are in the development stage. The Crystal Mine is operated through two tunnels, each over 1,200 feet long. The Goldsmith Mine is being operated from the 500 and 600-foot levels by a main shaft. Ore is shipped to the Washoe Smelter at Anaconda, and to the American Smelting & Refining Company at East Helena.

DAVIS-DALY COPPER CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., H. M. Burton; Sec'y-Treas., C. G. Schirmer; both Boston, Mass.
Operating Dept.: Mgr., C. L. Bruce, Butte; Supt., D. J. McGrath, Butte; Foreman, James White, Butte.
1300 H. P. Electric.
No. men employed: 400.
Ores: Copper and silver.
Daily output: 300 tons.
1918 output: 66,158 tons.

EAST BUTTE COPPER MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., Robt. H. Gross; Sec'y, Wm. P. Everts; Treas., Frank P. Son; all of Boston, Mass.
Operating Dept.: Gen. Mgr., Oscar Rohn, Butte.
Electric power.
No. men employed: 800.
Ores: Copper, silver, gold.

Miscellaneous Information: This company operates the properties of the Pittsmont Copper Company under an agreement entered into on April 8, 1909.

EAST BUTTE EXTENSION COPPER MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., Chas. J. Schatzlein, Butte; Vice-Pres., Philip A. Breen, Butte.
Operating Dept.: Gen. Mgr., Frank H. Cooney, Butte.
Ores: Copper and Silver.
Not operating at present.

ECONOMY MINES CO. **Helena.**

Location: Lewis and Clark County.
Officers: Pres., J. Kessner, Chicago, Ill.; Vice-Pres., S. Rosenfield, Helena; Sec'y, J. Rosenfield, Helena.
Operating Dept.: Mgrs., Rosenfield Brothers, Helena.
200 H. P. Electric.
No. men employed: 30.
Ores: Gold and silver.
Miscellaneous Information: Although development work is being done on the property, during the last year a 100-ton concentrating plant has been erected.

ELK GOLD MINING COMPANY. **Deer Lodge.**

Location: Racetrack Creek Mining District, 10 miles S. E. of Deer Lodge, Powell County.
Officers: Pres., C. E. Aspling, Deer Lodge; Trustees, I. S. Eldred and J. E. Nevill, Deer Lodge.
30 H. P. Steam.
No. men employed: 4.
Ores: Gold, silver, and copper.
Miscellaneous Information: Recently began sinking shaft.

ELM ORLU MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., W. A. Clark, Jr., Butte; Sec'y-Treas., W. D. Mangam, Butte.
Operating Dept.: Gen. Mgr., W. N. Rossberg, Butte.
3,000 H. P. Electric.
No. men employed: 500.
Ores: Copper, zinc, and silver.
Daily output: 600 tons.
1918 output: 208,651 dry tons combined zinc and copper ores.

GRANITE-BIMETALLIC CONSOLIDATED MINING CO. **Philipsburg.**

Location: Flint Creek Mining District, Granite County.
Officers: Pres., John P. Meyer; 1st Vice-Pres., Edward S. Orr; 2nd Vice-Pres., L. M. Rumsey; all of St. Louis, Mo.

Operating Dept.: Acting Supt., R. S. Blitz, Philipsburg.
No. men employed: 18; 96 leasers.
Ores: Silver.
Daily output: 30 tons.
1918 output: 27,429 tons.
Miscellaneous Information: 3,000 acres of ground. In early days this property was a large producer, but is now being entirely worked by leasers.

GLENGARRY MINING CO. **Cooke City.**

Location: New World Mining District, Park County.
Officers: Pres., J. T. Hamilton, Miles City; Vice-Pres., Charles Daly, Cooke City; Sec'y and Treas., C. H. Loud, Miles City.
Operating Dept.: Mgr., Charles Daly, Cooke City.
Hand Power.
No. men employed: 8.
Ores: Gold, silver, and copper.
Miscellaneous Information: Have just started to operate these mines, which have been idle for a number of years. Expect to get 10 cars marketed this season. This company is successor to the Montana Scotch Bonnet Copper and Gold Mining Co.

GOLDEN CURRY LEASING CO. **Elkhorn.**

Location: Elkhorn Mining District, Beaverhead County.
Officers: Mgr., M. I. Lydig, Elkhorn.
30 H. P. Electric.
No. men employed: 16.
Ores: Iron, gold.
Daily output: 30 tons.
Miscellaneous Information: Iron is mined for flux. Shipping to American Smelting & Refining Company.

GREAT BUTTE COPPER CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., F. W. Bacorn, Butte; Treas., Charles Hyde, 331 Fourth Ave., Pittsburg, Pa.
Steam and electric power.
No. men employed: Average 25.
Ores: Copper and zinc.
Miscellaneous Information: Doing extension work only.

HUGO GOLD AND COPPER MINING CO. **Saltese.**

Location: Denemora Mining District, Mineral County.
Officers: Pres., R. W. Seideman, Saltese; Vice-Pres., W. W. Woods, Wallace, Idaho.
Water power.
Ores: Gold and copper.

INGERSOLL MINING COMPANY. **Neihart.**

Location: Montana Mining District, Cascade County.
Officers: Pres., Allen Pierse, Great Falls; Sec'y-Treas., E. A. Shaw, Great Falls.

Ores: Silver and lead.
Miscellaneous Information: Property has been idle for several years, but arrangements are now being made to resume operations.

INTER MOUNTAIN MINING CO. **Iron Mountain.**

Location: Iron Mountain Mining District, Mineral County.
Officers: Pres., E. Evans, Post St., Spokane, Wash.; Vice-Pres., R. G. McIntosh, Spokane, Wash.; Sec'y-Treas., E. C. Danfer, Spokane, Wash.
Operating Dept.: Supt., P. L. Hoffman, Iron Mountain.
450 H. P. Electric, and 250 H. P. Water.
No. men employed: 75 (normally).
Ores: Copper, carrying some gold and silver.
Daily output: 150 tons.
Miscellaneous Information: At present only prospecting and developing, using 18 men.

JARDINE GOLD MINING & MILLING CO. **Jardine.**

Location: Sheepeater Mining District, Park County.
Officers: Pres. and Treas., W. S. Hunnewell, Drummond; Vice-Pres. and Gen. Mgr., H. C. Bacorn, Jardine.
300 H. P. Electric.
No. men employed: 50.
Ores: Gold and tungsten.
Daily output: 30 tons at present.
Miscellaneous Information: 40-stamp mill put in operation in 1919, handling about 150 tons of ore per day.

JIB MINING CO. **Basin.**

Location: Cataract Mining District, Jefferson County.
Officers: Pres., A. E. Spriggs, Helena; Vice-Pres., M. L. Hewett, Basin; Sec'y., Sol Genzberger, Butte.
Operating Dept.: Mgr., M. L. Hewett, Basin; Supt., R. Brinlori, Basin; Asst. Supt., Arthur Louiselle, Basin.

KENDALL LEASING CO. **Kendall.**

Location: North Moccasin Mining District, Fergus County.
Operating Dept.: Mgr., A. B. Fox, Kendall; Foreman, Frank Bryant, Kendall.
175 H. P. Electric.
No. men employed: 15.
Ores: Gold.
Daily output: Not regular.
1918 output: 7,152 tons.
Miscellaneous Information: The Kendall Mine is owned by the Barnes-King Development Co., successors to the Kendall Gold Mining Co., and is under lease to A. B. Fox and S. D. Whipple, working under the above name.

LAST CHANCE MINING CO. **Saltese.**

Location: Denemora Mining District, Mineral County.
Officers: Pres. and Mgr., Geo. Champagne, Saltese.
No. men employed: 2.
Ores: Silver, lead and copper.
Miscellaneous Information: Doing development work only.

LEGAL TENDER CONSOLIDATED MINES CO. **Clancy.**

Location: Lump Gulch Mining Dist., Jefferson County.
Officers: Pres., H. A. Gallwey, Butte; Sec'y, J. H. Heilbronner, Butte; Treas., Wm. Stussy, Butte.
Operating Dept.: Supt., D. J. Courtney, Clancy; Foreman, Wm. Murrey, Clancy.
75 H. P. Electric.
No. men employed: 25.
Ores: Silver.
Output: Irregular.
Miscellaneous Information: Mine producing an average of two cars a month, and extensive development work being done.

LEVIATHAN GOLD MINING CO. **Pony.**

Location: Mammoth Mining District, Madison County.
Officers: Pres., Chas. E. Morris, Pony; Vice-Pres., J. L. Templeman, Butte; Treas., Wm. C. Morris, Pony; Sec'y, James A. Flint, Pony.
Operating Dept.: Lessee, Ben W. Wilson, Jefferson Island.
Ores: Copper, gold, and silver.
Miscellaneous Information: For past two years this property has been under contract for sale and lease to B. W. Wilson. Matured payments have been made, with the probability of completion, which will put the above company out of business.

LITTLE NELL MINE. **Clancy.**

Location: Lump Gulch Mining District, Jefferson Count.
Officers (Operating Dept.): Gen. Mgr., Stanly A. Easton, Kellogg, Idaho; Mgr., H. H. Mayer, East Helena; Foreman, T. Brownlow, Clancy.
70 H. P. Steam.
No. men employed: 10.
Ores: Silver, lead, zinc.
Miscellaneous Information: At present doing development work only.

LIVERPOOL SILVER MINES CO. **Helena.**

Location: Spring Hill Mining District, Lewis and Clark County.
Officers: Pres., John W. Brien, Essex, Ontario; Sec'y., W. G. Burns, 27 State St., Boston, Mass.; Treas., James E. Simpson, 27 State St., Boston, Mass.
Operating Dept.: Mgrs., Frank Eichelberger and Chas E. Fryberger, Helena.
250 H. P. Electric.

No. men employed: 21.
Ores: Silver-lead sulphides.
Miscellaneous Information: Opened old levels and installed new headframe and hoist in 1919; hoisting steadily Dec. 1, 1919.

LUKENS HAZEL MINING CO. **Libby.**

Location: Snow Shoe Mining District, Lincoln County.
Officers: Pres. and Gen. Mgr., C. Ed. Lukins, Libby; Sec'y and Treas., Wm. Jennison, Libby.
Miscellaneous Information: At present this company is not working its mine, but is engaged in building a concentrator and power plant, which will use 600 H. P. electric power.

MAGINNIS MINE. **Maiden.**

Location: Giltedge Mining District, Fergus County.
Lessee: W. A. Young, Maiden.
60 H. P. Steam and gasoline power.
No. men employed: 10.
Ores: Gold and silves, with more or less lead and copper.
1918 output: About 150 tons.
Miscellaneous Information: What is known as the Maginnis Mine is owned by A. M. Holter, Helena, one-fourth interest, and Dartmouth Land Company, Great Falls, three-fourths interest.

W. D. MARLOW. **Livingston.**

Location: Park County.
Officers (Operating Dept.): Gen. Mgr., W. E. Renshaw, Idaho Springs, Colo.; Supt., O. V. Miller, Cooke City, Mont.
25 H. P. Gasoline.
No. men employed: 7.
Ores: Gold, silver, lead.
1918 output: 200 tons.
Miscellaneous Information: Just beginning daily production; mine has been idle for several years.

MONTANA CONSOLIDATED COPPER CO. **Comet.**

Location: Cataract Mining District, Jefferson County.
Officers: Pres., J. V. Allen; Treas., T. F. Lee; both 51 Wall St., New York.
Operating Dept.: Gen. Mgr., H. J. McKenzie, Basin.
300 H. P. Electric.
No. men employed: 10 (at present).
Ores: Silver, gold, copper, zinc, lead.
Daily output: 40 tons.
Miscellaneous Information: Mine closed down in August, 1919, to allow for reorganization preparatory to starting large scale mining and milling. Crew of 10 men keeping mine unwatered and in good shape.

MITCHELL & MUSSIGBROD, INC. **Garnet.**

Location: First Chance Mining District, Granite County.
Officers: Pres., Louis Mussigbrod, Garnet; Vice-Pres., J. Mokenland, Warm Springs; Sec'y, Albert Galen, Helena.
Leaser: Louis Mussigbrod.
60 H. P. Steam.
No. men employed: 18.
Ores: Sulphide ores, gold, and silver.
Miscellaneous Information: Installed K. & K. flotation plant in 1913, and started operation in February, 1919.

MONTANA OREWAY MINING DISTRICT. **Jackson.**

Location: Big Hole Mining District, Beaverhead County.
Officers: Pres. and Mgr., Wm. P. Jahnke, Wisdom; Sec'y., F. W. Scott, Chicago, Ill.; Treas., John D. Rankin, Chicago, Ill.
35 H. P. Steam and compressed air.
No. men employed: 15.
Ores: Copper, silver, lead, gold.
Miscellaneous Information: Two carloads shipped for demonstration purposes. Company expects to erect concentrator.

MONTANA RADERSBURG MINING CO. **Radersburg.**

Location: Cedar Plain Mining District, Broadwater County.
Officers: Pres., A. E. Spriggs, Helena; Sec'y, B. E. Matthews, Helena; Treas., C. A. Whipple, Helena.
Operating Dept.: Mgr., A. E. Spriggs, Helena.
25 H. P. Gasoline.
No. men employed: 4.
Ores: Lead, silver.
1918 output: 200 tons.

MOULTON MINING COMPANY. **Walkerville.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., W. A. Clark, Butte; Vice-Pres., W. C. Siderfin, Butte; Sec'y, J. C. Phillips, Butte.
219 H. P. Electric.
No. men employed: 20.
Ores: Copper and silver, zinc and lead.
Daily output: 40 tons.
1918 output: 3,000 tons.
Miscellaneous Information: Principally development work being done.

NORTH BUTTE MINING COMPANY. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., Robert Linton, New York; Vice-Pres., Joseph B. Cotton, New York; Sec'y-Treas., F. R. Kennedy, New York, N. Y.
Operating Dept.: Gen. Mgr., N. B. Braly, Butte; Supt., L. D. Frink, Butte.
3,600 H. P. Electric and steam.

No. men employed: 850.
Ores: Copper and silver.
Daily output: 880 tons.
1918 output: 465,389 tons.
Miscellaneous Information: At present operating at about 60 per cent. of full capacity.

PATTEN MINING CO. **Philipsburg.**

Location: Flint Creek Mining District, Granite County.
Officers: Pres., A. J. Johnston, Butte; Vice-Pres., Earle B. Patten, Philipsburg; Sec'y-Treas., J. K. Heslet, Butte.
Miscellaneous Information: Not operating at present.

PHILIPSBURG MINING COMPANY. **Philipsburg.**

Location: Flint Creek Mining District, Granite County.
Officers: Pres., John P. Meyer, St. Louis, Mo.; Vice-Pres., John H. Dieckman, St. Louis, Mo.; Treas., Firmin D. Fusz, St. Louis, Mo.
Operating Dept.: Supt., R. S. Blitz, Philipsburg; Asst. Supt., A. E. Fritzberg, Philipsburg.
700 H. P. Electric.
No. men employed: 225.
Ores: Manganese dioxide, silver, and copper.
Daily output: 75 tons.
1918 output: 42,480 tons.
Miscellaneous Information: Operating Algonquin, Bryant, True Fissure, Horton, and Hope Mines, and 300-ton concentrating mill.

PIEGAN-GLOSTER MINE **(See Barnes-King Development Co.).**

PITT COPPER MINING CO. **Keystone.**

Location: Mineral County.
Officers: Pres., John A. Lathwood, Pittsburg, Pa.; Vice-Pres., W. S. Markley, Pittsburg; Sec'y, W. D. Brewer, Pittsburg; Treas., J. H. B. Phillips, Pittsburg.
Operating Dept.: Supt., L. C. McHeffey, Keystone, Mont.
80 H. P. Gasoline.
Ores: Copper, lead, silver, gold, zinc.
Daily output: Mill capacity, 100 tons.
1918 output: 150 tons concentrates; 450 tons crude ore.
Miscellaneous Information: Not operating at present.

PITTSMONT COPPER COMPANY. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., Robt. H. Gross, Boston, Mass; Vice-Pres., James H. Reed, Pittsburg, Pa.; Sec'y-Treas., F. Ward Paine, Houghton, Mich.
Operating Dept.: Gen. Mgr., Oscar Rohn, Butte.

2000 H. P. Electric; 2000 H. P. Steam.
No. men employed: 500.
Daily output: 500 tons.
1918 output: 185,000 tons.
Miscellaneous Information: Properties of this company are operated by the East Butte Copper Mining Company under an agreement entered into April 8th, 1909.

POTOMAC COPPER COMPANY. **Potomac.**

Location: Missoula County.
Officers: Pres., W. P. Jahn, Milwaukee, Wis.; Vice-Pres., Paul A. Gow, Butte; Treas., Geo. E. Palmer, Butte; Sec'y, J. J. Harrington, Butte.
Operating Dept.: Supt., W. I. Higgins, Potomac.
85 H. P. Steam.
No. men employed: 30.
Ores: Copper and gold.
Miscellaneous Information: Development work only.

REVENUE MINES. **Norris.**

Location: Lower Hot Spring Mining District, Madison County.
Officers: De West Candee and Howard S. Candee; both 43 Exchange Place, New York.
Trustee: G. D. B. Turner, Norris, Mont.
Steam Power (installing 250 H. P. Electric).
No. men employed: 18.
Ores: Gold.

SCRATCH AWL MINING & DEVELOPMENT CO. **Philipsburg.**

Location: Flint Creek Mining District, Granite County.
Officers: Pres., J. R. Moyle, Butte; Vice-Pres., T. Tomich, Butte; Sec'y-Treas., W. N. Waugh, Butte.
Operating Dept.: Gen. Mgr., E. F. Shields, Philipsburg.
125 H. P. Electric.
No. men employed: 16.
Ores: Silver, lead, copper, zinc, and manganese.
Daily output: 5 tons.

SHANNON MINE **(See Barnes-King Development Company).**

SILVER CABLE MINING COMPANY. **Missoula.**

Location: Coeur d'Alene Mining District, Missoula County.
Officers: Pres. and Gen. Mgr., Jas. D. Corbett, Missoula; Vice-Pres., J. W. Kennedy, Missoula; Sec'y-Treas., Carl C. Mott, Missoula.
Hand power.
No men employed: 7.
Ores: Lead-zinc, with silver.
Miscellaneous Information: Development work only.

SILVER TIP MINING CO. **Troy.**

Location: Lincoln County.
Officers: Pres., J. P. Schmuck; Vice-Pres., Harry Rosenkop; Sec'y, R. H. Hutchin; all 310 Hyde Blk., Spokane, Wash.
Ores: Zinc, lead, silver.
Miscellaneous Information: Not operating.

SNOW STORM MINES CONSOLIDATED. **Troy.**

Location: Lincoln County.
Officers: Pres. and Gen. Mgr., Leo Greenough, Spokane, Wash.; Sec'y-Treas., W. J. Beaton, Spokane, Wash.
Operating Dept.: Asst. Mgr., R. E. Walters, Troy; Mill Supt., L. E. Warner, Troy; Mine Supt., Jack Grills, Troy.
1200 H. P. Electric.
No. men employed: 150 to 200.
Ores: Silver, lead, zinc, gold.
Daily output: 200 tons.
Miscellaneous Information: 1200 H. P. hydro-electric power plant; 5½ miles 36-inch gauge railroad; 300-ton daily mill capacity.

SOUTHERN CROSS MINE (A. C. M. Co.). **Southern Cross.**

Location: Deer Lodge County.
Officers: Supt., J. C. O'Brien, Southern Cross.
Electric power.
No. men employed: 85.
Ores: Gold in iron and lime.
Daily output: 90 tons.
1918 output: 45,000 tons.

STERLING MINING & MILLING CO. **Silver Camp.**

Location: Heddlestone Mining District, Lewis and Clark County.
Officers: Pres., F. W. Rader, Pullman, Wash.; Vice-Pres., W. H. Rader, Ellensburg, Wash.; Sec'y-Treas., L. O. Howard, Pullman, Wash.
Operating Dept.: Gen. Mgr., L. O. Howard, Pullman, Wash.; Resident Mgr., Archie McDonald, Flesher, Mont.; Supt., U. J. Jones, Flesher, Mont.
125 H. P. Steam.
No. men employed: 25.
Ores: Silver, lead, zinc.
Miscellaneous Information: Mine ready to produce 100 tons daily; mill running one shift.

ST. PAUL-MONTANA MINING CO. **Maiden.**

Location: Gilt Edge Mining District, Fergus County.
Officers: Pres., C. W. Amos, St. Paul, Minn.; Sec'y-Treas., Wm. Biadin, St. Paul, Minn.
Operating Dept.: Mgr., W. B. Coolidge, Maiden.
160 H. P. Steam.
No. men employed: 4.
Ores: Gold.

SYNDICATE COPPER MINING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., W. W. McDowell, Butte; Sec'y, W. E. Reynolds, Butte.
Miscellaneous Information: This company was a holding company for the Tuolumne Copper Mining Company and the Colusa Leonard Mining Company.

TARBOX MINING COMPANY. **Saltese.**

Location: Denemora Mining District, Mineral County.
Officers: Pres., Richard Daxon, Wallace, Idaho; Sec'y-Treas., John T. Ferguson, Wallace, Idaho.
Operating Dept.; Mgr., Richard Daxon, Wallace, Idaho.
150 H. P. Steam.
No. men employed: 10.
Ores: Lead, silver, zinc.

TENDERFOOT COPPER MINING CO. **Monarch.**

Location: Cascade County.
Officers: Pres., John Whitted; Vice-Pres., Dougold McCallum; Second Vice-Pres., Thomas Ashton; Treas., R. B. Noble; Sec'y, R. W. Berry; all Great Falls.
Hand Power.
Ores: Copper, gold, silver.
Miscellaneous Information: Developing ten mining claims, four of which are patented.

TIMBER BUTTE MILLING CO. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Mgr., W. A. Rossberg; Efficiency Eng., D. W. Buckby; Mill Foreman, R. McGillivray; Asst. Mill Foreman, T. C. Nilson; Research Eng., G. E. Sheridan; Concentration Eng., I. O. Proctor; all of Butte, Montana.
2300 H. P. Electric.
No. men employed: 200.
Ores: Concentrator treats Elm Orlu crude zinc ore, and retreats Colusa Parrot Copper Mining Company copper tailings.
Daily output: 700 tons zinc ore; 1,300 tons copper tails.
1918 output: 190,000 tons crude zinc ore; 387,000 tons copper tails.

TRIUMPH GOLD MINING CO. **Princeton.**

Location: South Boulder Mining District, Granite County.
Officers: Pres. and Treas., L. U. Loomis, Philipsburg; Sec'y, G. D. Loomis, Philipsburg.
40 H. P. Steam.
Ores: Silver, gold, copper, lead.
No. men employed: 20 (building road).
Miscellaneous Information: Installing an air compressor to sink main shaft; in development stage.

TUOLUMNE COPPER MINING COMPANY. **Butte.**

Location: Summit Valley Mining District, Silver Bow County.
Officers: Pres., Ed. Hickey, Butte; Vice-Pres., Wm. P. Jahn,

Milwaukee, Wis.; Sec'y, J. .J Harrington, Butte; Treas., Frank K. Nilson, Butte.
Operating Dept.: Gen. Mgr., Paul A. Gow, Butte; Asst. Gen. Mgr., Herbert M. Fay, Butte.
600 H. P. Electric.
No. men employed: 100.
Ores: Copper and silver.
Daily output: 100 tons.
1918 output: 25,000 tons.
Miscellaneous Information: Company owns Tuolumne, Main Range, and Colusa Leonard Extension Mines.

WAR EAGLE MINING CO. **Harlem.**

Location: Little Rockies Mining District, Chouteau County.
Officers: Pres., J. C. Arbogast, Harlem; Vice-Pres., Ike Duncan, Chinook; Sec'y-Treas., G. M. Everett, Harlem.
20 H. P. Gasoline.
Miscellaneous Information: Development work only.

WESTERN SMELTING & POWER CO. **Cooke.**

Location: New World Mining District, Park County.
Officers: Pres. and Gen. Mgr., G. L. Tanzer; Sec'y, J. J. Black; Treas., Geo. B. Baker; all Seattle, Wash.
Operating Dept.: Mgr., Wm. M. Tanzer; Mine Supt., F. A. Hancock; Elec. Eng., Ingvald Gronvold; all Cooke, Mont.
1000 H. P. Hydro-Electric.
No. men employed: 75.
Ores: Copper (Chalcopyrite), galena; all ores containing values in gold and silver.
Miscellaneous Information: Development work only.

WHITLATCH MINE. **Union ville.**

Location: Unionville Mining District, Lewis and Clark County.
Lessee and Operator: A. R. Shennan, Box 351, Helena, Mont.
80 H. P. Electric and Compressed Air.
No. men employed: 4.
Ores: Silicious gold and silver.
1918 output: 300 tons.
Miscellaneous Information: Development work only.

WICKES-CORBIN COPPER MINING CO. **Wickes.**

Location: Colorado Mining District, Jefferson County.
Officers: Pres., S. A. Balliet, Helena; Sec'y-Treas., L. C. Henry, Helena.
Ores: Silver, lead, and copper.
Miscellaneous Information: Development work only.

YELLOWSTONE MINING CORPORATION. **Cooke.**

Location: New World Mining District, Park County.
Officers: Pres., W. E. Wolfenden, Roanoke, Va.; Sec'y, Samuel T. Rhodes, Roanoke, Va.
Operating Dept.: Mgr., J. E. Wholey, Cooke, Mont.
Ores: Lead, silver, gold, and copper.
Miscellaneous Information: Shipped five cars from Stump Mine last year; surveying 15 claims for patent at present.

DIRECTORY OF MONTANA OPERATING COAL MINES

ANACONDA COPPER MINING CO., Coal Dept. — **Washoe.**

Location: Deer Lodge County.
Officers: Gen. Mgr. Coal Dept., F. W. C. Whyte, Anaconda; Supt., Thomas Good, Washoe.
500 H. P. Steam and Electric.
No men employed: 200.
Daily output: 900 tons.
1918 output: 147,774 tons.

ARMINGTON COAL CO. — **Armington.**

Location: Cascade County.
Operator: J. O. Rundall.
Mule Power.
No. men employed: 2.
Daily output: 15 tons.
Miscellaneous Information: Property just opened.

BAYES COAL MINE. — **Bayes.**

Owner: Victor Stoban, Bayes.
No. men employed: 2.
Daily output: 6.
1918 output: 300 tons.

BEAR CREEK COAL CO. — **Bearcreek.**

Location: Carbon County.
Officers: Pres., Peter Yegen, Billings; Vice-Pres., J. Harry Wright, Bearcreek; Sec'y-Treas., C. P. Hamriet, Bearcreek.
Operating Dept.: Supt., C. P. Hamriet, Bearcreek.
250 H. P. Electric.
No. men employed: 185.
Daily output: 800 tons.
1918 output: 135,000 tons.

BIG SANDY COAL MINE. — **Big Sandy.**

Location: Chouteau County.
Proprietor: C. C. Mack, Big Sandy.
Foreman: Chas. Tivoni, Big Sandy.
Hand power.
No. men employed: 3 to 8.
Daily output: 10 tons.
1918 output: 2,700 tons.

BROWN COAL COMPANY. **Sand Coulee.**

Location: Cascade County.
Officers: Pres., J. W. Freeman, Great Falls; Vice-Pres., John L. Ross, Great Falls; Sec'y-Treas., Ernest Downing, Great Falls.
Operating Dept.: Mgr., Ernest Downing, Great Falls; Supt., John Latham, Sand Coulee; Outside Foreman, Carl Schmidt, Sand Coulee.
Electric power.
No. men employed: 98 to 105.
Daily output: 525 tons.
1918 output: 109,295 tons.

BRIDGER COAL MINING CO. **Bridger.**

Location: Carbon County.
Officers: Gen. Mgr., W. E. Pinkney, Bridger; Cashier, J. S. Emmett, Bridger.
500 H. P. Electric.
No. men employed: 20.
Daily output: 40 tons.
1918 output: 9,088 tons.

CARBON COAL & COKE CO. **Sand Coulee.**

Location: Cascade County.
Officers: Pres. and Mgr., Geo. Wilson, Sand Coulee; Vice-Pres. and Treas., H. E. Dawson, Sand Coulee; Sec'y, Anthony Morton, Sand Coulee; Supt., Wm. Navin, Sand Coulee.
350 H. P. Steam and Electric.
No. men employed: 80.
Daily output: 400 tons.
1918 output: 102,248 tons.

CHESTNUT HILL COAL CO. **Storrs.**

Location: Gallatin County.
Officers: Pres., John Aakjer, Bozeman; Treas. and Supt., William Maxey.
Miscellaneous Information: Development work only.

EAGLE COAL COMPANY. **Bearcreek.**

Location: Carbon County.
Officers: Pres., J. T. Flaherty, Red Lodge; Vice-Pres., H. A. Simmons, Red Lodge; Sec'y. and Treas., J. V. Flaherty, Red Lodge; Mgr., J. T. Flaherty, Bearcreek; Foreman, J. F. Lobdell, Bearcreek.
60 H. P. Electric.
No. men employed: 30.
Daily output: 150 tons.
1918 output: None.

GASS COAL MINE. **Yates.**

Location: Wibaux County.

Operator: A. R. McCloskey, Yates.
80 H. P. Steam.
1918 output: 1,200 tons.
Miscellaneous Information: Closed on account of litigation.

HELL GATE COAL CO. **Missoula.**

Location: Missoula County.
Officers: Pres., S. H. Draper, Missoula; Vice-Pres., E. S. Hathaway, Missoula; Treas., H. L. Shapard.
60 H. P. Electric.
Miscellaneous Information: Not operating.

INDEPENDENT MINING CO. **Roundup.**

Location: Musselshell County.
Owner: G. J. Jeffries, Roundup.
75 H. P. Electric.
No. men employed: 30.
Daily output: 150 tons.
1918 output: 50,000 tons.

INTERNATIONAL COAL CO. **Bearcreek.**

Location: Carbon County.
Officers: Pres., W. A. Talmage, Joliet; Sec'y-Treas., J. Harry Wright, Bearcreek; Gen. Mgr., W. H. Franklin, Bearcreek.
300 H. P. Electric and Steam.
No. men employed: 75.
Daily output: 300 tons.
1918 output: 53,620 tons.

JACKMAN COAL MINING CO. **Near Forest Grove at Jackman Spur.**

Location: Fergus County.
Officers: Vice-Pres., John B. Ritch, Lewistown; Sec'y-Treas., E. W. Mettles, Lewistown.
Hand power.
No. men employed: 10.
Daily output: 25 to 30 tons.

MACKTON COAL CO. **Big Sandy.**

Location: Chouteau County.
Officers: Pres. and Mgr., W. R. Hensen, Chinook; Sec'y-Treas., Hans H. Lehfeldt, Big Sandy; Supt., L. S. Proctor, Big Sandy.
500 H. P. Electric.
No. men employed: 5 to 50.
Daily output: 25 tons.
1918 output: 8,300 tons.

MILK RIVER COAL CO. **Chinook.**

Location: Blaine County.
Officers: Pres., Jurgen Kuhr, Chinook; Vice-Pres., William Duke, Chinook; Treas., Thomas O'Hanlon, Chinook; Foreman, Clarence Sargent, Chinook.
No. men employed: 10.
Daily output: 35 tons.
1918 output: 7,765 tons.

MILLARD COAL COMPANY. **Belt.**

Location: Cascade County.
Officers: Mgr., H. W. Millard, Belt.
28 H. P. Electric.
No. men employed: 7
Daily output: 40-50 tons.
1918 output: 3,292 tons.

MONTANA COAL & IRON CO. **Washoe.**

Location: Deer Lodge County.
Officers: Pres., Thos. M. Kearney, Racine, Wis.; Vice-Pres. and Mgr., J. M. Freeman, Washoe; Asst. Treas., George McMillan, Washoe.
Operating Dept.: Gen. Mgr., J. M. Freeman, Washoe; Supt., W. R. Freeman, Washoe; Sales Mgr., George McMillan, Washoe.
300 H. P. Steam and Electric.
No. men employed: 564.
Daily output: 1,500 tons.
1918 output: 307,606 tons.
Miscellaneous Information: Operating two mines in Bearcreek field.

NATIONAL COAL MINING CO. **Sand Coulee.**

Location: Cascade County.
Officers: Pres. and Mgr., Jas. R. Brown, Sand Coulee.
150 H. P. Electric.
No. men employed: 52.
Daily output: 210 tons.

NELSON COAL COMPANY. **Sand Coulee.**

Location: Cascade County.
Officers: Pres. and Treas., J. W. McClure, Great Falls; Vice-Pres., Geo. E. McClure, Great Falls; Sec'y, M. W. Hanks, Stillwater, Minn.
Operating Dept.: Mgr., J. W. McClure, Great Falls; Foreman, Geo. Cooley, Sand Coulee; Mine Mgr., Harry Thomas, Sand Coulee.
200 H. P. Electric.
No. men employed: 100.
Daily output: 500 tons.
1918 output: 161,348 tons.

PEARCE COAL COMPANY. Sand Coulee.

Location: Cascade County.
Officers: Pres., Dan Tracy, Great Falls; Vice-Pres., H. P. Brown, Great Falls; Sec'y-Treas., Wm. Thornton, Great Falls; Supt., Robert Lindsay, Sand Coulee.
45 H. P. Electric.
No. men employed: 22.
Daily output: 94 tons.
1918 output: 37,332 tons.

PEERLESS COAL MINE. Plentywood.

Location: Sheridan County.
Operators and Owners: Pierce & Wheeler, Plentywood.
12 H. P. Electric.
No. men employed: 3.
Daily output: 20 tons.
1918 output: 6,838 tons.

PINE CREEK COAL COMPANY. Pray.

Location: Park County.
Officers: Gen. Mgr., George H. Bottamy, Livingston; Mine Supt., Harry Bottamy, Pray; Sales Agt., George H. Brown, Wilsall.
Operating Dept.: Operator and P. A., George H. Bottamy, Livingston; Sec'y-Treas., G. Henry Bottamy, Livingston.
100 H. P. Steam, and Mule.
No. men employed: 10.
Daily output: 10 to 20 tons.
1918 output: 1,200 tons.

PUTNAM COAL CO. Culbertson.

Owner: Mrs. E. Putnam, Culbertson.
Hand Power.
No. men employed: 3.

REPUBLIC COAL CO. Roudup.

Location: Musselshell County.
Officers: Pres., E. D. Sewall, Chicago, Ill.; Vice-Pres., James Needham, Chicago, Ill.; Chief Eng., C. F. Brenn, Chicago, Ill.
Operating Dept.: Supt., Wm. Redshaw, Roundup; Master Mechanic, Albert Gately, Roundup.
1250 H. P. Steam and Electric.
No. men employed: 525.
Daily output: 3,000 tons.
1918 output: 663,267 tons.

ROUNDUP COAL MINING CO. Roundup.

Location: Musselshell County.
Officers: Pres., G. W. Megeath, Omaha, Neb.; Vice-Pres., W. F. Megeath, Omaha, Neb.; Treas., G. A. Rehm, Omaha, Neb.

Operating Dept.: Gen. Mgr., H. S. Hopka, Roundup; Chief Eng., L. J. Cake, Roundup; Supt., John Sanderson, Carpenter Creek.
800 H. P. Electric.
No. men employed: 600.
Daily output: 3,600 tons.
1918 output: 530,000 tons.

SMOKELESS AND SOOTLESS COAL CO. **Washoe.**

Location: Deer Lodge County.
Officers: Pres., J. F. Brophy, Red Lodge; Vice-Pres., J. S. Brophy, Frostburg, Md.; Sec'y, K. C. Brophy, Red Lodge; Gen. Mgr., J. F. Brophy, Red Lodge.
Electric Power.
No. men employed: 85.
Daily output: 200 tons.
1918 output: 48,385 tons.

STULLER & TRIPLETT. **Froid.**

Location: Sheridan County.
Owners: J. C. Stuller and Ira Triplett.
Horse Power.
No. men employed: 4.
Daily output: 12 tons.
1918 output: 2,500 tons.

THOMSEN MINE. **Plentywood.**

Location: Sheridan County.
Owner: Hans Thomsen, Plentywood.
Horse Power.
No. men employed: 3.
Daily output: 18 tons.

WEST BUTTE COAL CO. **Westbutte.**

Location: Toole County.
Owner: P. J. McDermott, Westbutte.
No. men employed: 4.
Daily output: 6 tons.
1918 output: 981 tons.

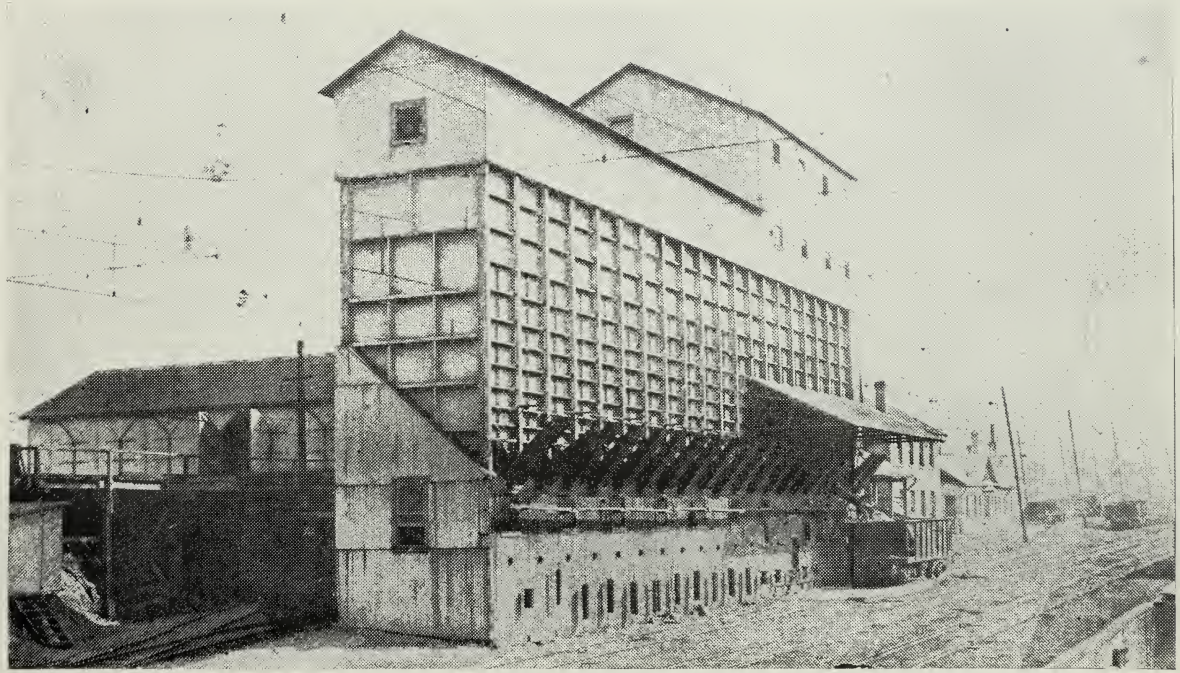

FIG. 1.—THE WASHOE SAMPLER OF THE ANACONDA MINING COMPANY, AT BUTTE, MONTANA.

UNIVERSITY OF MONTANA BULLETIN

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MECHANICAL ORE SAMPLING IN MONTANA

By H. B. PULSIFER

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INTRODUCTION

AUTHORIZATION

The bill creating the Montana State Bureau of Mines and Metallurgy, enacted by the Legislative Assembly of Montana for 1919 (Chapter 161, Page 311), states that it is one of the objects and duties of the new bureau, "To study the mining, milling, and smelting operations carried on in the State, with special reference to their improvement", also, "To prepare and to publish bulletins and reports, with necessary illustrations and maps, which shall embrace both a general and detailed description of the natural resources and geology, mines, mills, and reduction plants of the State."

OBJECT

A study of sampling and the sampling facilities of Montana is presented, in accordance with the above authorization, to widen and deepen the general knowledge relating to the common and necessary, yet rather technical work of sampling. It is hoped that prospectors and miners will benefit from the study, for their interests have been kept prominently in view. The sampling mills in which ore sellers will find personal interest have been thoroughly studied and their reliability tested by an expensive series of samplings to demonstrate their precision on an ordinary lot of ore. It is felt that even small advances toward the uniformity, precision, and efficiency of sampling mean so much to the industry as to warrant even far more effort and cost than is represented in this study.

ACKNOWLEDGMENTS

The managements of the American Smelting and Refining Company, the Anaconda Copper Mining Company, and the East Butte Copper Mining Company have heartily welcomed the study and have assisted in every way possible. Each company has put itself to expense and trouble to join in the work.

Particular acknowledgments are due Messrs. Smith, Morse, and Adams of the American Smelting and Refining Company, to Messrs. Laist, Bender, Gillie, Margetts, and Demond of the Anaconda Copper Mining Company, and to Messrs. Rohn and Beaudin of the East Butte Copper Mining Company. The men mentioned have been personally helpful in forwarding and correcting the work.

Dr. Clapp of the State Bureau has taken a strong interest in the work and helpfully directed the preparation of the report.

THE PURPOSE OF SAMPLING

The sampling of a lot of ore is carried out in order to supply the analyst with a 4-ounce envelope of finely ground powder which, when selections are made in from half-gram to thirty-gram portions, shall give the analyst average results with a precision of about one part in fifty for the important components, or elements, moisture excepted. The usual chemical determinations are for gold, silver, copper, lead, zinc, sulphur, iron, silica, lime, and magnesia, and for special elements in particular ores.

Sampling is thus seen to have an amazing purpose in view; to take from a lot of ore—be it one ton, fifty tons, or five hundred tons—only about thirty-two ounces of material which shall uniformly contain all the components of the original lot in exactly the proportions in which they exist in the original lot of ore. Even this final sample of about thirty-two ounces must be capable of division so that the different packets into which it is separated must be chemical duplicates of each other and supply seller, buyer, control analyst, smelter, and umpire analyst with as nearly identical results as possible. Yet, in spite of the enormous difficulties in practice, perfectly satisfactory sampling is actually attained daily.

The lot of ore to be worked upon will likely contain very fine material, sandy material, and sizes up to big chunks; it will contain desirable minerals and undesirable rocky gangue; it may contain free metals, clayey gouge, and crystals in all degrees of purity. It is remarkable that the task can be done at all; it is nothing less than one of the great achievements of modern engineering and industry that it can be done easily, quickly, cheaply, and with precision.

Ordinary sampling mills will secure a 100-pound sample from a 50-ton lot of ore in from fifteen minutes to two hours, and then from this sample the sample man in the bucking room will produce the analyst's packets of thoroughly ground, dried, and mixed pulp in another hour.

The cost of sampling varies from 5 cents to $1.50 a ton, depending upon the amount, character of ore, and the method and equipment used.

Sampling has accomplished its purpose if the small packet will supply the half-gram, fifteen-gram, or thirty-gram selections for the analyst so that he can get his results with the required precision. The sampling is satisfactory if the average results on different selections from the same packet, or on selections from different packets, or on selections from different samplings, agree to one part in fifty parts, or, as they sometimes do, to one part in one hundred parts. The precision may be less with elements present in excessively small amounts, like gold and silver. The chemical work is subject to both constant and chance errors, so that single results, or too many significant figures in the results, have little meaning; error may come as likely from the analytical work as from the sampling operation.

Sampling has failed of its purpose if selections from packets do not agree within the desired limits, or if the different packets from the same sampling do not agree, or if packets from different samplings are discordant. The best test of accuracy in sampling is to resample or sample by another method. It is rarely cheap or practicable to actually extract the desired metal or attempt to separate a compound from an entire large lot in order to determine its amount; in such a case the recovery figure, instead of the composition figure, is obtained, because the losses which the chemist compensates for, the plant operator cannot avoid.

Whoever mines ore, sells it on the results of the analysis of a sample; ore is purchased on its value as determined by sampling; the plants are operated on a basis of results from sampled materials; efficiencies and losses are all based on results from samplings. Sampling is therefore one of the most vital and necessary operations of modern mining and metallurgical industry.

PRINCIPLES OF SAMPLING

*Woodbridge in a recent paper published by the United States Bureau of Mines defines sampling as follows: "The correct sampling of a lot of ore is the process of obtaining from it a smaller quantity that contains, in unchanged percentages, all the constituents of the original lot." He further qualifies and defines the operations in his next paragraph: "The commercial object of sampling is accomplished when the ultimate sample obtained meets the above conditions within an allowable limit of error, and has been obtained with reasonable speed and at a moderate cost. The final sample should be dry and of such bulk and degree of fineness as to be immediately available for the determination by the assayer or chemist of one or more of its constituents."

THE OPERATIONS OF SAMPLING

Four wholly different, yet essential, sorts of work may be done to accomplish the intended purpose of sampling. The four operations are:

1. Crushing, or grinding.
2. Selecting—dividing or cutting.
3. Mixing.
4. Drying.

These essential operations are carried through to varying degrees and in whatever order the conditions require. Thus, with flotation

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*Woodbridge, J. T.; U. S. Bureau of Mines, Technical Paper 86 (1916).

concentrates, which are already finely ground and well mixed in production, the work is largely in cutting out numerous selections, drying, regrinding the lumps made by the drying, mixing the pulp, and dividing it between the several packets. A lot of coarse, rocky ore may be dry and excessively hard; in this case the work is mostly crushing and selecting until the small final portion is dried, finely ground, mixed, and split for the assayers' packets.

Successful sampling demands that a rational sequence be followed and that attention be continually give to certain fundamental conditions, explained later, lest some slip or unexpected influence vitiate the entire work. It is self-evident that the final result cannot be more perfect than the most imperfect step in the sequence; if six divisions are made, and one is imperfectly done, perfect work in the other five does not compensate.

Sampling can frequently be accomplished by different methods or by changing the sequence of the steps; one usually uses the method most feasible or least costly. Thus, if one had a 50-ton lot of lump ore to sample, an imaginary way to get the required results might be to dry the entire lot, then grind it to pass 100 mesh, then mix it thoroughly, then at last take out just enough of the dried, ground, and mixed ore to fill the sample packets. For most metallurgical purposes the cost of such an operation would be absolutely prohibitive; the nearest commercial approach to it is probably the sampling of the Cobalt native silver ores. The usual western practice with lump ores is to crush to 2- or 3-inch size, select a fifth and crush it finer, select a fifth and crush it again; and this sequence is repeated, two, three, four, or more, times, until a small amount is obtained which alone is dried, finely ground, mixed, and distributed between the packets.

The method of making the entire lot uniform and then selecting a few duplicate portions for the analyst is attractive for the ease and simplicity of the few selections involved. In addition, this method is one which may come into use more and more on account of the lines along which metallurgy and industrial chemistry are advancing. Pipe sampling of concentrates is almost an example of this simple method. In fact, this method is actually followed in the most approved manner of sampling lead bullion. A kettle of molten lead ready for casting into bars is stirred for 15 minutes; as the stirring continues the sampler inserts a steel rod, with a row of conical depressions in it. On the withdrawal of the rod each little cone of lead, which fills a depression, will come out of the kettle of the proper weight for the assayer and will contain the correct proportions of all components of the kettle of molten lead. Two lots of 7 little cones, all from the same kettle, were cupelled, and the following results were obtained:

	Series No. 1		Series No. 2	
	Gold	Silver	Gold	Silver
	.30 oz.	81.7 ozs.	.30 oz.	82.1 ozs.
	.30	82.0	.30	82.4
	.30	81.4	.30	82.0
	.30	82.3	.30	81.7
	.32	82.1	.30	82.0
	.30	82.0	.30	82.0
	.30	82.3	.32	81.8
Average:	.30	82.0	.30	82.0

This method of sampling lead bullion has given eminently satisfactory results at a trivial cost. Pipe sampling of a pile, or carload of concentrates, is also a matter of very slight cost and will necessarily give correct results if the lot is uniform. Sampling by taking a few small portions from a uniform lot of fine material, either during its production or after it is in a batch, is a method which should always be borne in mind; and if the proper condition for this is to araise during the treatment of any material, sampling can be profitably delayed until that stage is reached. Unfortunately, the producer of ore seldom has his material in a fine and uniform condition suitable for such sampling.

Crushing and Grinding.—The crushing of ore for sampling purposes is largely a matter of mechanics, power, and capital outlay. It usually does no harm if some of the material is finely divided during the course of crushing the larger pieces to the necessary dimensions. Since a great variety of sizes will inevitably be produced, the making of fines increases the number of particles and favors the sampling when it is done on the probability basis.

Many of the crushing machines on the market are excellent for reducing ore sizes and fulfil most of the expected functions. Capital outlay is always a serious consideration and machines are primarily installed on their gross capacities and not on the basis of how thoroughly they will accomplish the crushing task. Sampling mills do have a strong claim for heavy and powerful machinery, since an unusually large or tough piece of rock slipping through one machine may spoil the sampling because of its excessive mass and one-sided composition. In ordinary ore-dressing practice it means little if slabs fall through machines or if large rocks spring the rolls and fail to be well crushed. Ultimately the pieces will be caught and crushed or returned to the first crushers by the sizing devices. But most sampling mills do not have sizing devices and it is possible for large pieces to get into the sample. It is not uncommon to find a sample which, although 90 to 99 per cent. is properly sized, contains a few unduly large pieces, thus tending to vitiate the results.

Several methods may be proposed for overcoming the sizing difficulty. The idea of using very heavy rolls is neither new nor impres-

sive. Dodge type crushers, which make a finer product than the Blake type, would be only a partial remedy. There appears to be a field for a type of crushing machine which shall be so constructed as to make the passing of thin slabs impossible; capacity could be somewhat sacrificed for the sake of the sizing feature.

In regard to grinding the finest sizes for the final pulp there appears to be an open field for studying the correlation of grinding substance with the work accomplished. A complete study of this detail of sampling and grinding should include the composition, structure, and physical properties of the grinding substance. One important factor would be to accurately determine how much of the grinding substance is abraded to contaminate the sample.

Dividing or Selecting.—The phrase, "selecting the sample," could well be replaced with the words, "dividing the lot," for the idea inherent in SELECT is that a division is made which is based on some property or quality of the portions available. The word select is always used in this paper with the simple meaning of divide. The most vital principle in any and all sampling is that division shall not be dependent on any quality of the parts. Whether one is removing a small portion of a perfectly mixed lot, or whether one is making a thousand mechanical divisions, the separation demands the absence of discrimination.

Mechanical sampling attains its best precision with well-designed equipment which allows no division based on a property of parts, as on the coloring, the sizes, or the relative densities of the ore pieces. If a piece of machinery is to handle pieces of rock several inches across just as impartially as it handles quarter-inch sizes it probably means surprisingly large equipment. When confronted with the problem of sampling very large pieces, the engineer sometimes decides to crush enough to accommodate the sampling machinery; he rarely builds ungainly machinery, but he frequently handles large sizes with too small machinery. To the mechanical engineer a compromise is a "practical" solution of the problem, but to the mining engineer a compromise involving even slight deviations from impartial sampling is a perversion of the whole function.

The precision of modern mechanical sampling, as based on the law of probability brought into play by hundreds and thousands of divisions, is a source of much pride and satisfaction to the engineers and men interested. The demonstrations to be presented in later paragraphs will substantiate this opinion and establish a confidence in the practice. Mechanical cutters in the mills, and riffle dividers in the bucking rooms, allow ores to be sampled without possibility of being influenced either by human craft or stupidity. Also, fortunately, both speed and cheapness are in favor of wholly mechanical sampling.

Mixing the Sample.—The mixing of a large lot of ore consisting of large and small pieces is almost impossible and, besides, is wholly

useless. When you try to do this you find that any method of handling assorted sizes allows segregation if the material is dropped, or let roll, or even moved by ordinary implements. The material cannot be properly sampled by small selections of single pieces, because the larger pieces exceed the proportionate composition in all components.

The mixing of large lots of fine ore or mill products is not as difficult an operation as the preceding, but is seldom practicable unless done incidentally to the production or transfer of the material. Even if a lot of fine ore appears to be uniformly mixed there is no easy demonstration of the fact, and it is much safer to depend on a considerable number of cuttings. The frequent division of a fairly uniform material is carried out in practice when mill streams are sampled, either mechanically or by hand, when cars and bins of concentrates are pipe sampled, and in shovel sampling by the tenth- or fifth-shovel method. The three instances last mentioned are really applications of probability sampling, but probability sampling used where the material is known to be nearly uniform, and where from 50 to 500 selections suffice to establish the required precision in the sample.

A thorough mixing of the final portion of pulp previous to its division between the several packets is indispensable. A large number of rollings on a suitable cloth or paper is the almost universal way to do the final pulp mixing. Rolling, when skilfully done, accomplishes the purpose, but the great objection to rolling is that it is tedious and requires both time and patience. If a cloth fabric is used it may well have a pebble-grained surface; a paper should have a matte surface. The surfaces of either fabric or paper are commonly colored black to show the sample more easily.

Substitutes for rolling the pulp on cloth or paper have been proposed; the Anaconda sample mills use cube mixers and at the School of Mines a small table riffle answers the purpose. At Anaconda both mills are equipped with 8-inch cube mixers which rotate by power and slowly enough for the contents to undergo practically the same sort of tumbling which a pulp would get when rolled on a fabric. Cube mixers have not proved satisfactory in all cases and their use in the State is limited to the Anaconda mills. Classes in assaying at the School of Mines have recently mixed their final pulps by pouring them, with shakings to and fro, at least ten times through a table riffle. As far as can be determined in the the course of the regular assaying work, the riffle mixing is fully adequate and will be explained in considerable detail.

A riffle cutter may be used to make either a very few or a greater, and almost unlimited, number of cuts during the division of an ore sample. Figure 2 shows an operator pouring a sample through a riffle cutter which has 26 slots. When the sample container rests on the edge of the cutter, and the material is merely allowed to flow through the 12 slots which extend the width of the ore stream,

FIG. 2.—STAND RIFFLE CUTTER USED AT THE STATE SCHOOL OF MINES.

The cutter has 26, 5/8-inch slots, and is intended for dividing 8-mesh stock.

there will be 6 streams of ore flowing into the sample half, and the lot may be said to be cut 6 times for sample. When the operator moves the container across the top of the riffle, say 20 times during the pouring, all of the slots are brought into play and the lot may be cut 20x13, or 260, times for sample. The operator might, however, take the ore from the container in a scoop and then pour it through in small portions, shaking each scoopful 20 times across the riffle. If the operator takes a lot of ore in 10 scoopfuls, and pours each across the 26 slots, with 20 to and fro motions, he makes, altogether, 10x13x20, or 2,600 cuts, for the sample.

It is thus seen that a lot of ore is very easily cut into a larger number of portions by merely shaking the ore stream across the riffle. When the two halves of the divided sample have been united the lot of ore has been thoroughly mixed. Both gross and minute inequalities are dispersed throughout the sample by cutting and uniting several times, in other words, the lot has become unusually "well mixed."

The author is of the opinion, that, if a lot of sample pulp is shaken 10 times across a riffle, which makes 1,000 cuts for sample each time, the united pulp will be as well mixed as by rolling 1,000 times on a cloth. The riffle mixing can be done in less than 5 minutes, while the rolling will rarely require less than 15 minutes.

In order to make an exacting test of the mixing that can be done with a riffle the author prepared 500 grams of quartz and 500 grams of iron ore by grinding each and passing them through a 100-mesh sieve. Each lot was, of course, dry and thoroughly mixed. The iron ore was poured over the quartz in a pan and then the material was poured through a 12-slot riffle giving nearly 100 shakes during the 30 seconds required for the powder to flow from the pan. Two grab samples of about half-gram size were taken on a spatula from each half. The two portions were united and the operation repeated. This was done 7 times and each time two grab samples from each half were taken for analysis. The chemical results were as follows:

Quartz, 3.17% iron; iron ore, 43.78% iron; average, 23.48% iron.

PERCENTAGE OF IRON IN GRAB SAMPLES

Mixing	The Four Samples				Average	Ave. Deviation from 23.48
1st	15.72	32.72	6.04	30.80	21.32	10.44
2nd	20.24	20.12	19.24	21.12	20.18	3.30
3rd	20.12	21.40	23.40	22.88	21.95	1.51
4th	23.28	23.50	23.40	23.20	23.34	.15
5th	23.64	23.64	23.44	23.64	23.61	.13
6th	23.56	23.64	23.44	23.64	23.57	.11
7th	23.36	23.44	23.52	23.64	23.49	.09

The chemical analyses show that the first mixing had intermixed the iron ore and quartz to a very considerable extent, although far

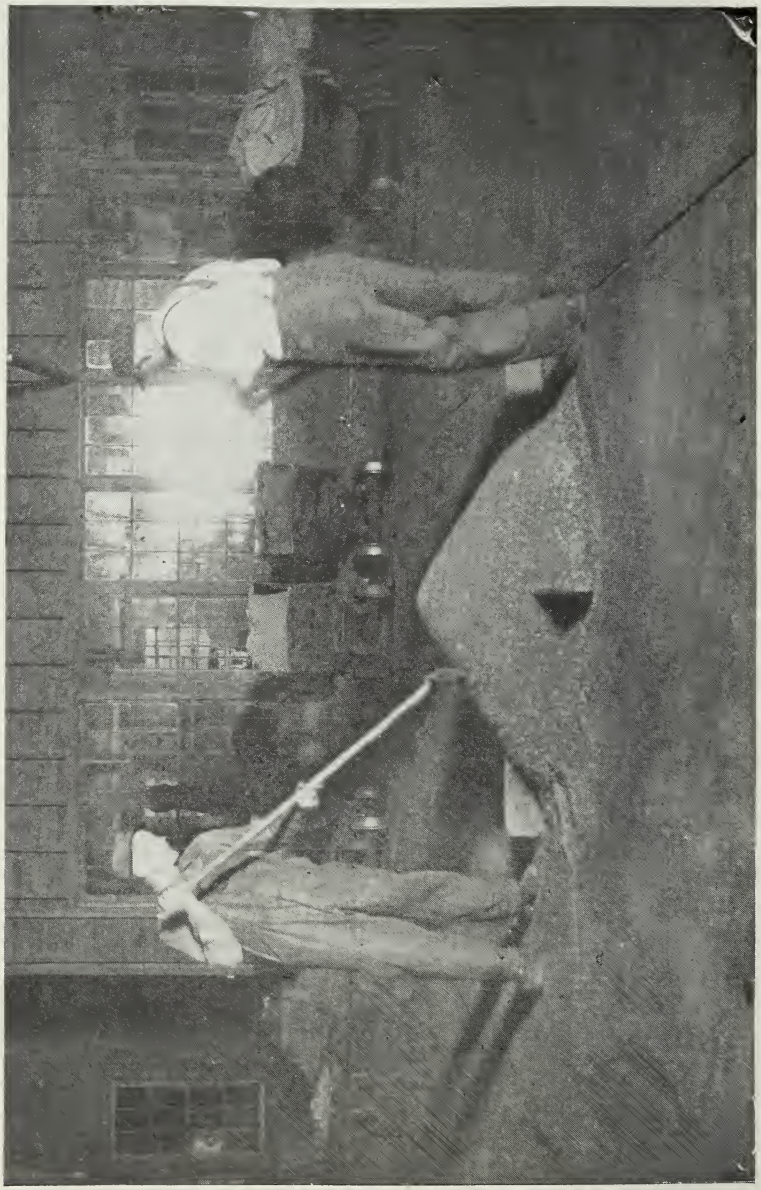

FIG. 3.—CONE AND QUARTER SAMPLING.

The cone has been formed over a wooden cross and the men are just beginning to spread the pile.

from enough to be utilized. The second mixing adjusted the composition to within a few per cent. of what it should be. The third mixing brought practically perfect final composition in streaks, while the fourth mixing doubtless rendered the entire batch homogeneous to within 1 part in 100 parts, which is of the order of the chemical analyses, themselves. The 5th, 6th, and 7th mixings changed the composition in an almost inappreciable degree. The chemical determination of iron was chosen because it could be done more easily and with greater precision than almost any other determination or assay.

Material which yields identical composition on haphazard samples fulfills the test of uniformity, in this instance rather a test of the mixing than anything else.

Whenever the riffle cutter has been tested under proper conditions it has given admirable results; it is, accordingly, strongly recommended wherever it can be used. The prospector and miner will find riffles both cheap and handy. Riffles can be used wherever cone and quarter sampling or split shovel sampling is now used. The utmost use of riffles will tend toward uniformity, low cost, rapidity, and the greatest possible precision in sampling.

Drying the Sample.—Two devices are in common use in Montana for drying ore samples; the most common is the cabinet shelf dryer, heated by steam or electricity; steam tables with large flat tops are also found at most mills. The shelves of the cabinet dryers will accommodate pans large enough to hold eight or ten pounds of ore in a thin layer. Larger samples are divided among pans or spread on the steam table. An hour's drying is usually considered enough, although the sample may be left in the dryer much longer while awaiting its turn for fine grinding.

Drying is by far the simplest and easiest of the four mechanical operations in ore sampling.

The drying problem, if indeed there is any, is rather one of procuring a sample to dry, or taking the moisture sample, then drying the sample after it is procured. At some Montana mills the sample for moisture is a composite made up of several cuttings from different places well within the lot, at other mills a somewhat arbitrary correction is made to the moisture on the regular mill sample, or on a portion of the last mill crushings. How to get a moisture sample cheaply and accurately is the same sort of problem as how to cheaply and accurately sample spotty gold ore; both are troublesome.

CONE AND QUARTER SAMPLING

There is a method for sampling ores, handed down through many decades, which is known as the cone and quarter process and is supposed to have originated in Cornwall. The ore is thrown into a conical pile, which is then spread out with a tool as the operator

FIG. 4.—CONE AND QUARTER SAMPLING.
The first cone is being ringed to mix the fine, damp material.

circles about the pile. Quarters are marked and two opposite ones are shoveled away, leaving one-half of the original lot as a sample. The coning and quartering is repeated as often as necessary to get the right-sized sample. Figure 3 shows the operation in progress on a steel sampling floor.

The principle involved in cone and quarter sampling is that of symmetry about a vertical axis; an additional and less effective principle is that of compensation of opposite quarters. The idea in the cone and quarter method is that the ideal pile shall be uniform about the center, but, if the pile is not uniform, the opposite sectors across any given diameter may be expected to compensate for each other and so establish a working average. The method of dividing the lot allows the principle of diagonal compensation to apply to both sample and discard.

Although splendid work can be done by the cone and quarter method the principles are not as simple nor is the work as independent of human discrimination as sampling by other methods. An exaggerated segregation of fine and coarse particles always occurs during the coning of the pile; depending entirely on the ensuing distribution of the finer core of the pile, there may be either a fair halving or a preponderance of values in either sample or reject. Mixing the lot by "ringing about" before coning is a common practice (see Figure 4). The use of crosses to help center the pile and hold the sides during the division is also common practice.

PROBABILITY SAMPLING

The law of averages and the theory of probability demonstrate that if either single pieces or small portions of a large lot are chosen at random the composition of the selection will approach, after enough selections and as a limiting condition, the composition of the entire lot. Obviously, if one selects the entire lot, the sample and lot become identical. However, it is not necessary to take the entire lot, for by mixing and taking a sufficient number of single particles, or by making enough cuttings, or by a combination of mixing and dividing, it is possible to take not more than one-fifth, one-tenth, or even one-twentieth of the lot and still get a truly representative sample. Shovel sampling, split shovel sampling, riffle sampling, and all types of mechanical cutters involve more or less of the probability principle.

To make the probability overwhelmingly on the side of precision, a questionable number of divisions is not taken, but thousands of divisions, each portion containing thousands of particles, are commonly made. Furthermore, the possibility of large pieces influencing the results is precluded, and any influence that can interfere with absolutely random division is avoided. Thus any influence which tends to select according to size, weight, shape, density, color, hardness, porosity, or any other imaginable property is eliminated.

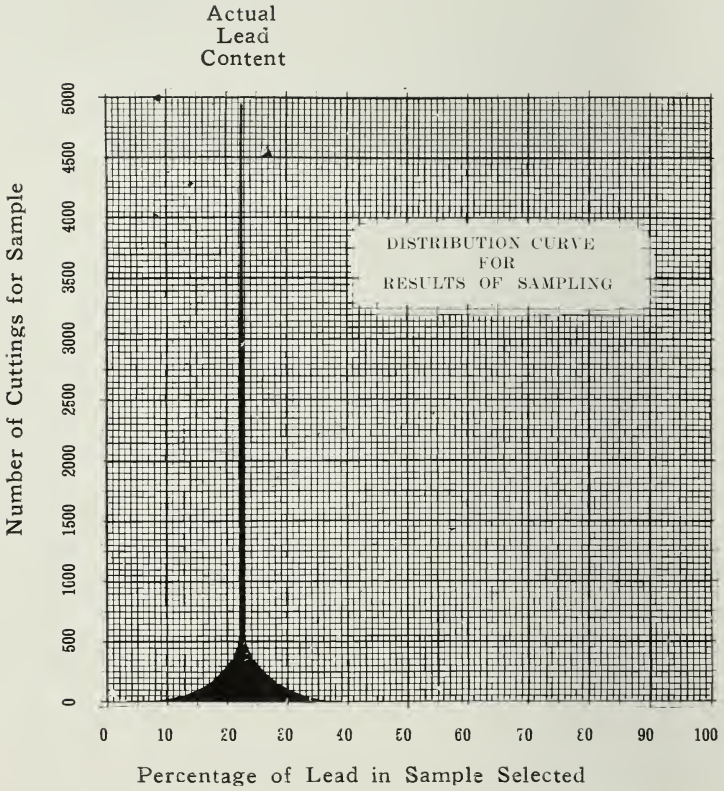

FIG. 5.—PROBABILITY CURVE FOR DISTRIBUTION OF SAMPLING RESULTS.

There is no doubt but that the results of sampling must follow some probability curve, mathematically determinable by the factors and quantities involved; the engineer makes certain that the curve shall be of the shape indicated in Figure 5. The curve means that, depending on the number of divisions or cuttings for sample, the probable result will lie within the extremely narrow, vertical portion of the blackened area. On this basis, if one repeatedly crushes between divisions so as to circumvent the influence of large single particles, the limit of accuracy is not exceeded, although the crushing and dividing is repeated as many times as necessary to sufficiently reduce the size of the sample.

In actual sampling the sequence of crushing and cutting is commonly performed from six to ten times. Each portion of the thousand or more selections made by one machine contains millions of particles and the final result has every assurance of correctness and is capable of proof. The proof consists, not in analyzing the entire lot, which, as already stated, is impossible, but in repeating the process, in getting duplicate samples, or by sampling by an entirely different method.

If a lot of ore weighing 50 tons requires 60 minutes to go through a mill whose mechanical cutters are taking out a fifth at the rate of 60 cuts a minute and are in series of four, the first cutter will make 3,600 selections and take out 10 tons containing millions of particles. After crushing, the second cutter will make its 3,600 selections from the first sample and take out its 2 tons containing again millions of particles. Then the third cutter will divide the 2-ton lot, making its 3,600 selections and taking out 800 pounds containing again some millions of particles. The last cutter will divide the 800 pounds and with its 3,600 selections take out 160 pounds in another sample likewise containing millions of particles. The process of crushing and dividing is then continued with suitable machines, and usually in the bucking room, until the final analysts' packets, each containing millions of particles, represents the original lot with the same precision as that of any previous larger selection or sample.

THE LARGEST PIECES

The goal to be attained in the most economical crushing and dividing is to crush the larger particles no more than necessary to prevent their one-sided composition affecting the accuracy of the results. The limiting size of particle is of course a constant depending on the nature of the material and the quantity of the lot. The earlier sampling mills in the western United States were strongly constrained to crush as little as possible, because the ore was desired coarse for blast furnace smelting. The combined considerations of economy and preserving the ore coarse have given us most of the mill characteristics which are found in western samplers. The mills have been built and operated largely on an empirical basis, with thorough studies on the vital factors conspicuously absent. The limiting sizes for

different ores, minerals, and weights of lot is one of the studies on which comparatively little work has been done in a systematic way.

In a general way, and as far as practicable, the present sampling mills are constructed to so crush the larger pieces that when a division is made there shall be no excessively large pieces. An excessively large piece is one which would materially affect the result, depending on whether it enters the sample or the reject. The mills are intended to make thousands of what may be termed the largest-sized pieces. A few of the larger pieces cannot, then, by getting in the wrong division, appreciably affect the result.

Some investigators have supposed that the law of averages would apply to the larger pieces in this way, that even if some excessively large and rich pieces should tend to increase the values in the samples there would be enough large lean pieces to conterbalance. Weld[1], in 1910, clearly demonstrated, by actual tests, that it is not admissible to use this interpretation of the probable distribution of results. A probability curve based on the average obtained by balancing a few large and individually important quantities would be much broader and flatter than the curve indicated in Figure 5.

The accuracy of the sampling operation is jeopardized in two ways by the presence of unsuitably large pieces; the presence of the piece affects the results, and it interferes with the work of the dividers. The common occurrence of pieces larger than intended is commented upon by Woodbridge[2] in his paper on western sampling practice.

In 1895, Brunton[3] published a paper containing an extensive discussion on the safe size of the largest pieces for lots of ordinary ores and low-grade gold ores. Woodbridge[4] gives a table, based partly on Brunton's work and partly on experiments and practice, designating the smallest permissible weight of sample for different sized material. If it is necessary to have at least a certain amount of material for pieces of a given size, the converse statement must also hold, that if a lot of ore weighs only a given amount, then the largest pieces must have only the corresponding size.

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1 Weld, "Accuracy in Sampling," J. Ind. Eng. Chem., Vol. 2 (1910), page 426.

2 Woodbridge, T. R.; "Cre-Sampling Condition in the West." U. S. Bureau of Mines, Technical Paper 86, page 57 (1916).

3 Brunton, D. W.; "The Theory and Practice of Ore-Sampling." Trans. Am. Inst. Min. Engrs., Vol. XXV., page 826 (1895).

4 loc. cit.

The table, as given by Woodbridge, follows:

Smallest Permissible Weight of Sample for Varying Sizes of Crushing

When Crushed To—	Smallest Permissible Weight, Pounds
Two inches	10,000
One and one-half inches	5,000
One inch	2,000
Three-fourths of an inch	1,000
One-half inch	400
Three-eighths of an inch	300
One-fourth inch	200
Three-sixteenths of an inch	100
One-eighth of an inch	75
Six-mesh	50
Ten-mesh	25
Eighteen-mesh	10
Thirty-mesh	4
Fifty-mesh	1

Woodbridge applies the table to ordinary gold ores and suggests that the limits may be too restricted for low-grade silver ores. The relationships expressed in the table may well be adhered to for the sake of allowing a reasonable margin of safety. The common presence of ore pieces larger than the allowable size, frequently seen in Montana practice, is a condition which can be excused only because of the comparatively low grade of the ores.

HIGH VALUE MINERALS

The influence of pieces of coarse gold in a lot of ore is so overwhelming as to make any table of quantity-size relationships of little value. Oxidized surface gold ores and quartz containing coarse gold are in places so rich that single pieces may easily vitiate the sample by whole ounces. Accurate sampling of such materials demands that the entire lot should be finely ground before dividing. It is usually admitted that ordinary sampling mills are not adapated to sampling ores contaning coarse gold; it is also obvious that it would not pay custom plants to install fine-grinding machinery for the small and infrequent lots of "spotty" ores.

The prospector or miner who is getting out rich material and thinks he is not getting fair returns can install a small grinding machine and daily reduce to 20- or 40-mesh the few hundred pounds of ore he produces. A suitable grinder need not cost over $200.00, and with whatever power is available the small operator should be able to pulverize his high-grade ore so that any good method of sampling will give accurate results.

EQUIPMENT FOR SAMPLING

Several really difficult and obstinate conditions are met in the satisfactory execution of the principles of sampling, so that to do the work quickly, cheaply, and above criticism demands high engineering accomplishment. Modern precision and modern standards are always becoming more exacting, and although the last few years have brought few changes in the industry, there is yet opportunity for further work.

CRUSHING AND GRINDING

The following machines are about the only ones used in sampling plants to reduce the size of ore particles:

a. Gyratory rock breakers—for the largest sizes.
b. Jaw crushers, Blake type—for large and medium sizes.
c. Rolls—for intermediate and small sizes.
d. Bell-type grinders—for small and finest sizes.
e. Disk grinders—for the finest sizes.
f. Bucking boards—for the finest sizes.

Baby gyratories and chipmunk crushers are now and then seen in laboratories, but their place is for special samples rather than for routine samples of large lots.

The large crushers used in sampling works are always commercial mill units. The practice is a great convenience to the sample mill designer, but, as already mentioned, the ordinary ore crushers are not perfectly adapted to sampling, because it is possible for flat and rather large pieces to get through the crushers without suitable reduction. Single pieces entering a spring roll may be suitably crushed, but if several pieces enter together, or within a wave of fines, one or more pieces may fail to be crushed because the rolls opened under the strain.

The wear of the hard iron working surfaces is usually compensated by adjusting the opening, but the channeling of the jaws and the corrugation of roll shells takes place just as in any concentrating mill. As the sampling mills do not contain sizing and returning equipment unless for some additional function of the mill, it follows that samples frequently contain pieces far too large for the size of the sample.

The introduction of abraded iron into the sample during the fine grinding is a matter upon which data is apparently rather scanty. Fieldner[1] reports that the ash in five samples of coke was increased, on the average, 2.9% by grinding on a bucking board instead of in a pebble mill. The quartz used in the author's mixing test contained only 0.03% iron extractable from the small rounded grains, but 3.17% iron after grinding in the disk grinder.

1 Fieldner, A. C.: "Notes on the Sampling and Analysis of Coal." U. S. Bureau of Mines, Technical Paper 76, page 57 (1914).

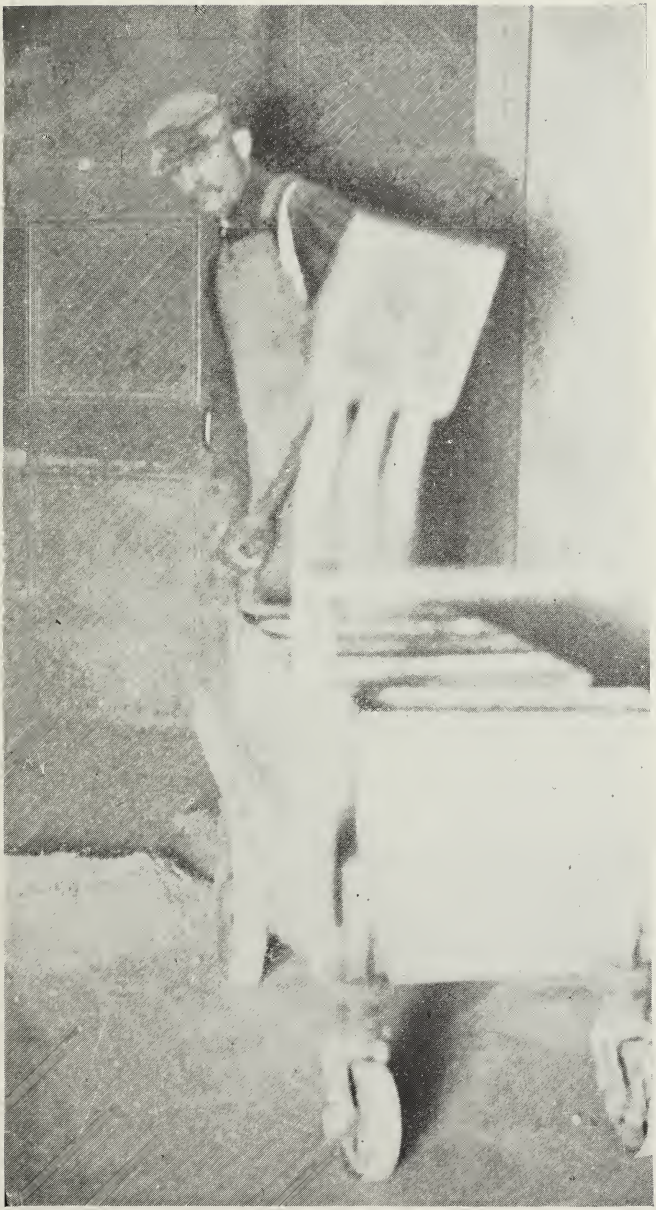


FIG. 6.—SPLIT SHOVEL SAMPLING.
The sample man is sliding the reject into pans; the sample is held in the pockets and will be piled and again divided.

DIVIDING INSTRUMENTS

The Hand Shovel.—The division of a lot of ore into sample and reject by shoveling it over, and putting every fifth or tenth shovelful aside as the sample, is an old and useful method of sampling. The size of the pieces and the richness of the minerals must, of course, correspond with the lot size, while the restricted number of selections infers that the lot has received some mixing.

There are evidently 1,000 selections made for sample if a 50-ton lot of ore is hand shoveled in 10-pound shovelfuls, and every tenth one is put to one side as the sample. As the size of the sample decreases the number of selections gets critically small, but is in a measure compensated for by the mixing.

The method of shovel sampling is easily carried out if the material has to be moved by hand and is fine enough. Crushing must be introduced at the required stage if the material is not fine to start with. It is a common practice to shovel sample for the first, or first two divisions, and finish with the cone and quarter method.

For nearly all large scale metallurgical work shovel sampling is far too slow and costly; the method also suffers because of the carelessness of the workmen and because of an undesirable element of judgment in handling lots of mixed sizes.

The Split Shovel.—The split shovel is in common use in some of the Montana sampling plants. It offers a convenient means of dividing a lot, but the number of independent cutting which can be made is small. It makes no difference how few selections are made if a lot of ore is well mixed, but in practice it is nearly always easier to make many cuts than it is to mix the ore. Figure 6 shows a sample man sliding the reject from a split shovel into discard pans. Material remaining in the closed pockets of the shovel will be piled and cut again.

Riffle Cutters.—The widely-used Jones type of riffle sampler, built either as a floor stand or in table size, is a remarkable instrument for dividing and mixing ore samples. Suitable designs have from 16 to 40 slots, are rigidly made, and have the slots wide enough to safely accommodate the particles poured over them. The ratio of 4 to 1 is generally considered a safe one with which to express the "width of opening" over "diameter of particle" relationship. This ratio is usually greatly exceeded when riffling small sizes and is often far from being attained when riffling coarse material. The instrument well deserves to be given both more variety in manufacture and more use in the industries.

Figure 2 shows the 26-slot stand cutter used at the Montana State School of Mines. Figure 7 shows a riffle with alternate bottoms closed, but as the cutter is fixed on a sharp slope it is a Jones riffle to all intents and purposes; this cutter is in use in several Montana

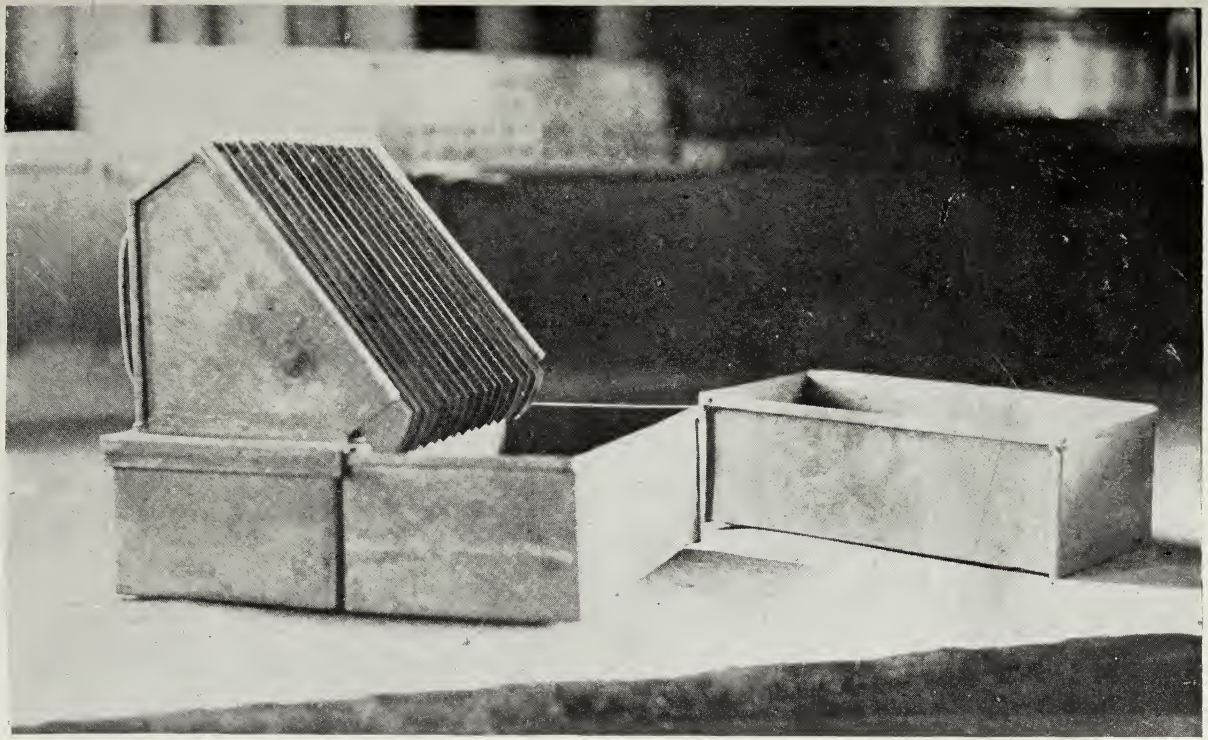


FIG. 7.—INCLINED TABLE RIFFLE.

This cutter has 16 slots. A similar cutter with 30 slots and half the slot width is more often used.

FIG. 8.—CORNER IN EAST HELENA BUCKING ROOM.

Bucking boards, scales, riffles, cabinet dryer, sieves, and sample holders can b
seen.

mills. In Figure 8 is seen a neat table riffle at the very left of the picture; this design is in use at the mills of the American Smelting & Refining Co. at East Helena, Montana.

Pipe Samplers.—Pipe samplers have long been used in Montana and in other sections of the country, notably at the zinc mines in Missouri and Oklahoma, where the cars of concentrates are sampled with the "gun," as the pipe sampler is there called, immediately after loading out for the smelters. Since the advent of flotation concentrates, which are notoriously sticky and difficult to handle, pipe samplers have greatly increased in utility in the Butte district.

Ore suitable for pipe sampling consists of concentrates or other fine material which has been produced in a regular and uniform manner, or has been mixed in handling. Flotation concentrates may very in consistency from a thin mud to a dry powder. When sampling carloads of the muddy concentrates men are sometimes barely able to support themselves on the drying crust. Cars which have traveled long distances may have the load so firmly packed that an auger, rather than a pipe, is required to cut out the samples.

According to the Montana practice, lots of concentrates are sampled at the mill by the shipper and later at the custom sampling plant, or smelter. Data as to agreement of assays is not available, but results are said to be wholly satisfactory.

Pipe sampling of a carload of concentrates usually begins at one end of the car, where a row of holes two feet apart and two feet from the end wall is made; a parallel row is then punched two feet nearer the center and this is repeated until samples are taken in a systematic order over the entire length of the car from points about two feet apart. Hopper-bottomed cars have the two deep pits, which are hard to penetrate, but the pipes are long enough to touch the steel bottoms, as in the shallowed portions of the car.

Pipes are commonly four to five feet long, three inches diameter at the top and two inches at the cutting edge. For firm materials, easily cleared, circular tubes are used; for sticky loads the pipe is slotted and provided with a scraper with which the sample man quickly forces the core out into the sample pan. A sample of 250 pounds weight is usually obtained by from 40 to 75 insertions of the pipe. Figure 9 shows three men sampling a car of flotation concentrates at the Washoe Sampler.

Pipe sampling of the fine concentrates may continue in the bucking room until the final samples for moisture and assay are taken. The sample man merely goes over the pans of first sample with a smaller pipe, a foot long and an inch in diameter, and punches from all parts of the pans enough cores to give a sample of the required weight.

The justification of pipe sampling clearly depends on the uniformity of the lot of ore as it is spread in the bin or car. To test the uniformity of a lot of concentrates in a railroad car, the author took

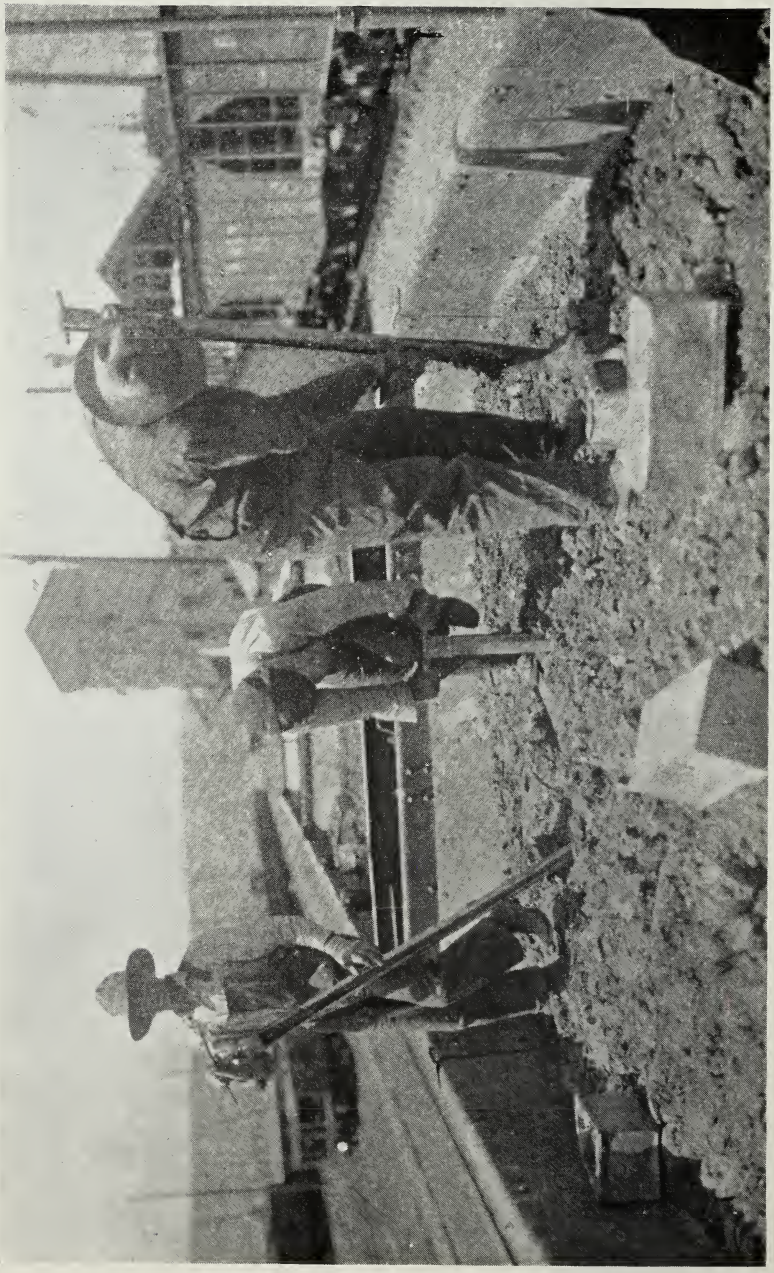


FIG. 9.—PIPE SAMPLING OF FLOTATION PRODUCT.

40 four-ounce grab samples from the pipes as a car of flotation concentrates was being sampled at a custom plant. Each of the samples was dried, ground, mixed, and analyzed for iron with the following results:

Sample	%Fe	Sample	%Fe	Sample	%Fe	Sample	%Fe
1	14.7	11	14.1	21	13.4	31	14.8
2	14.2	12	14.8	22	15.5	32	16.2
3	13.8	13	14.5	23	13.1	33	15.7
4	14.5	14	13.8	24	13.1	34	16.3
5	14.0	15	14.5	25	13.1	35	17.2
6	14.2	16	14.1	26	18.3	36	15.4
7	14.3	17	13.2	27	13.8	37	14.8
8	14.1	18	13.6	28	14.5	38	15.3
9	15.0	19	12.8	29	14.8	39	17.4
10	13.0	20	15.0	30	15.0	40	14.3

The average of all the figures is 14.7%, and the average deviation of a single analysis is only .9% from the 14.7%. In other words, the average deviation from the mean is approximately 1 part in 15. From the sampling point of view it means that one could take a grab sample anywhere in the car and the probable analysis of that sample would be accurate to better than 1 part in 15.

The main pipe samples, from which the little samples just discussed were taken, weighed 25 to 30 times as much and were piled and again piped before drying, mixing, and grinding for the regular sample. The main sampling work might reasonably be expected to be 10 times as accurate as the author's grab sampling, which would make the main pipe sampling accurate to more than 1 part in 150, a precision considerably greater than ordinary assaying or wet chemical analysis.

Pipe sampling of fine, mixed materials is very rapid and cheap; the test confirms the prevalent opinion that it is also accurate.

The Brunton Vibratory Cutter.—One of the earliest sample cutters used in western sampling mills consists of a thin wedge of steel plates riveted to a shaft and set in the center of the ore stream as it flows from a spout. The thin wedge has the shaft inclosed along its base and points upward into the ore stream; by turning the wedge to one side or the other it deflects the entire ore stream first to one side, then to the other side; separate spouts catch the two ore streams made by the deflector. Spill is taken care of by steel wings on each side of the wedge or blade. The sample can be made any fraction of the lot by the relative periods the deflector remains pointing toward either sample or discard spout. Pins on a rotating disk engage a cam at the far end of the shaft and so throw the blade, first to one side, then to the other; by the adjustment of the pins in holes around the edge of the disk the periods are determined and the periods, in turn, determine the fraction selected for sample.

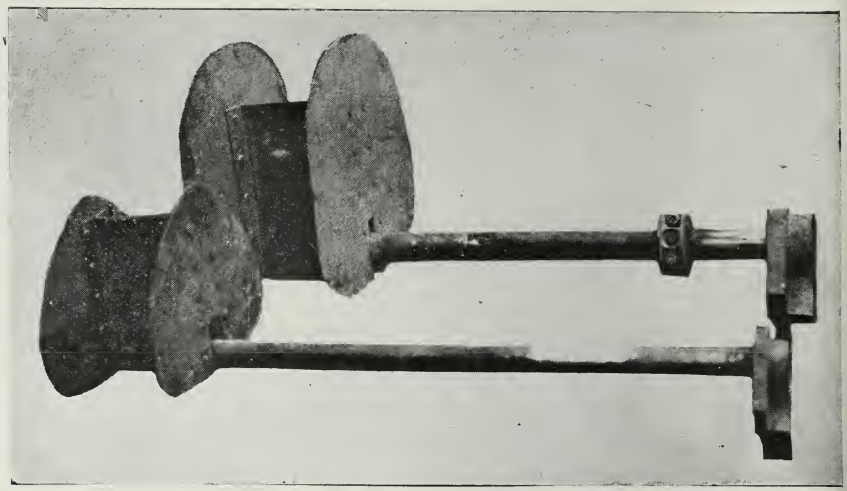


FIG. 10.—BRUNTON VIBRATORY CUTTER BLADES.

Two sizes as used in one of the East Helena Sampling Mills.

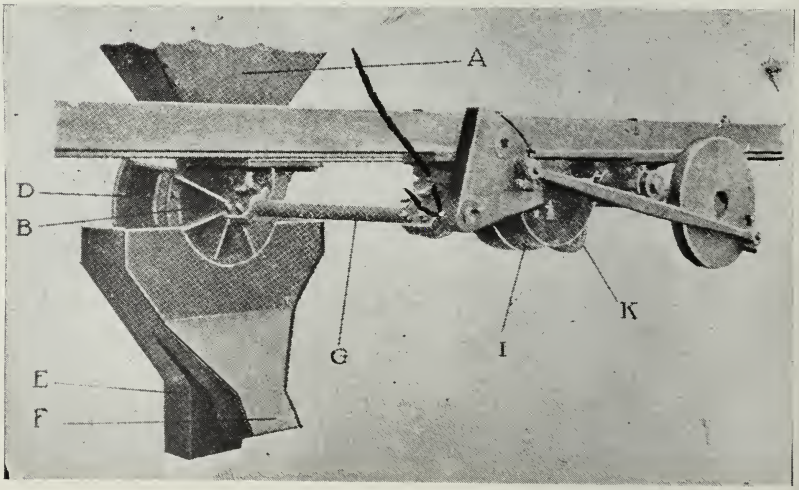


FIG. 11.—MECHANISM OF BRUNTON OSCILLATORY SAMPLER.

A crank arm on a disk changes the rotary motion of a pulley to the oscillations of the cutter.

(After Brunton, Trans. Am. Inst. Min. Engrs., 1909.)

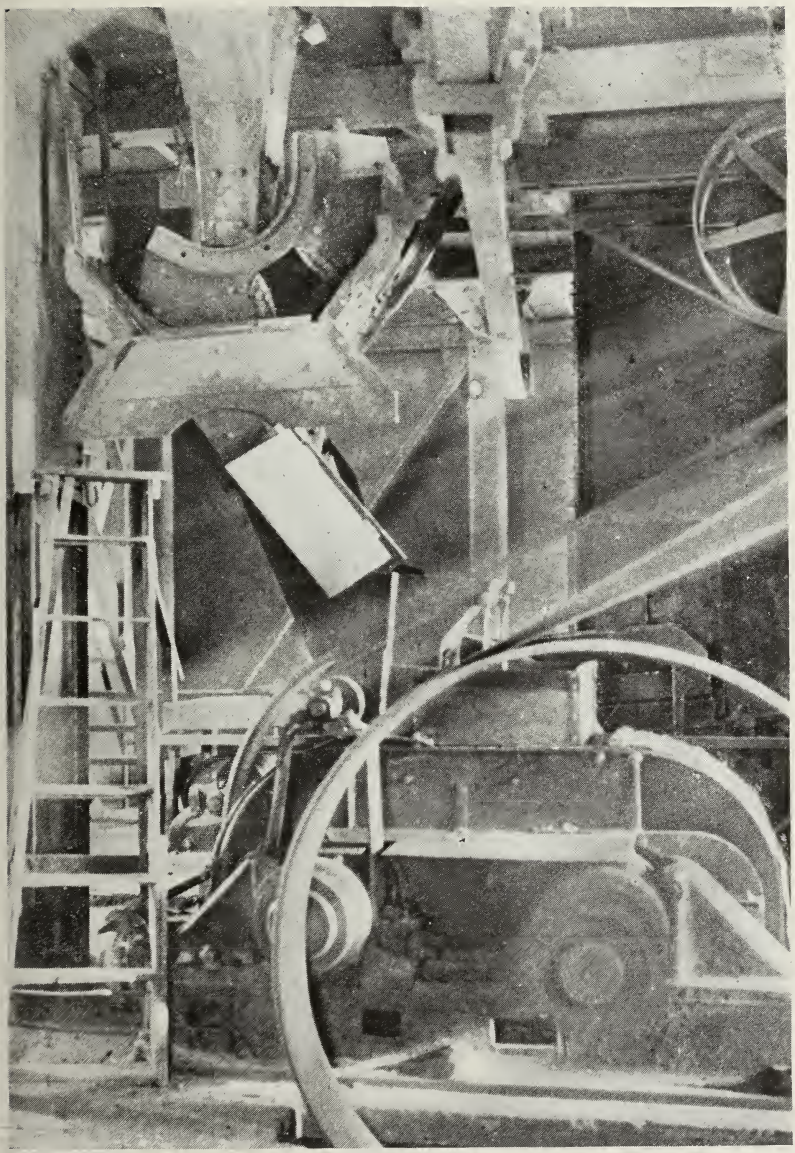


FIG. 12.—FIRST SAMPLER AND ROLLS AT THE WASHOE SAMPLER.

The steel housing in front of the oscillator is turned down to expose the parts. The sample drops through the opening and falls to the rolls, the reject is deflected away to a spout to the conveyor behind the rolls.

Two sizes of Brunton vibratory cutter blades are seen in Figure 10; they happen to be spare parts for the machines now used in only one mill in Montana.

The vibratory cutter slips through the ore stream quickly, which is always an advantage; the blade also cuts the stream in the same direction for sample. If the repeated cutting in the same direction is considered a disadvantage, it is eliminated in the Brunton oscillatory cutter, which is next described. The driving mechanism of the vibratory cutter would doubtless have been further perfected if the oscillatory cutter had not been invented.

The Brunton Oscillatory Cutter.—In the States of Colorado, Montana, Nevada, and Utah are many sampling mills built after the Taylor and Brunton design and equipped with the Brunton "time-sampler", or oscillatory cutter. The general scheme of the driving machanism is plain after studying Figure 11, while a cutter is seen in place in Figure 12.

The cutter is of the general intersecting saucer type, but the machine oscillates back and forth across a 120° arc and its cutting edges enter the ore stream first from one side, then from the other, instead of always from the same side. The small sample cut is plainly made by a division of the stream, the deflecting planes entering first from one side, then from the other. The division of the ore stream is smooth and clean-cut, while the driving mechanism is noiseless and lasting. The wearing parts of the oscillatory cutter are the edges of the sample segment and the floor of the larger reject casting; the small sample casting can be frequently renewed at slight expense, thus maintaining the cutting edges, while the larger casting is renewed as often as worn out.

The East Butte Cutter.—Figure 13 illustrates the mechanical cutter used at the East Butte mill. It rotates in a horizontal plane and is obviously of the intersecting saucer type. The unit seen in Figure 13 has 4 sample openings and would make a 20% selection, the units actually in place in the mill have 2 openings and make about 10% selections. The cutters are entirely suspended from above and the ore stream enters them either vertically or at a steep angle.

The Vezin Cutter.—The Vezin type of mechanical cutter is made in several modifications of the original intersecting cone type. In all forms the lower cone, either real or imaginary, is extended upward on two opposite arcs in a sort of wing design; it is into the rotating wings that the sample falls and is discharged through the restricted lower apex of the cone. It is well to compare this machine (Figure 14) with the East Butte cutter and note that both are closely related; by merely altering the relative sizes of the parts, the sample or the discard is made to fall through the apex of the inverted cone.

FIG. 13.—EAST BUTTE TYPE OF SAMPLER.
This cutter has four slots; the cutters installed have only two slots.

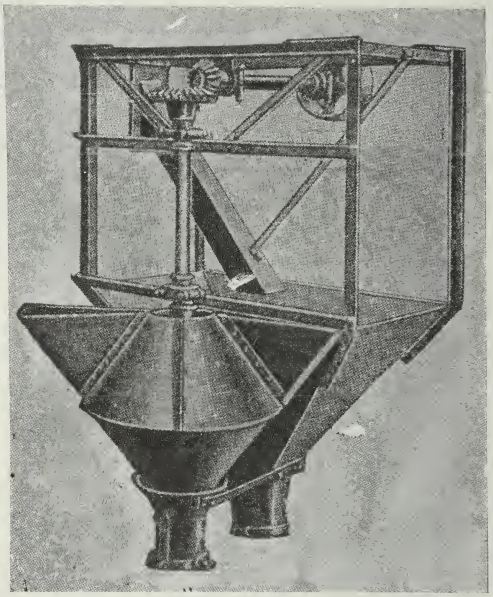


FIG. 14.—VEZIN SAMPLER.
Several modifications of the type are in common use. This is the design supplied by Traylor Eng. & Mfg. Co.

The Snyder Sampler.—A slotted saucer, rotating on a horizonal axis, forms the base idea of the Snyder sampler. A sloping feed spout neatly directs the stream of ore through the inclined opening as the sample slot passes. The similarity to the several other intersecting saucer types is apparent from Figure 15. The machine usually has two sample lots, as seen in the picture, but the only unit known to be installed in Montana, which is a 28-inch machine in the ore-dressing laboratory of the State School of Mines, has a single slot.

The actual amounts of sample cut by the various samplers is an important topic which has not been thoroughly investigated. The only data which the author has seen are figures obtained by the Anaconda Copper Mining Company. These figures indicate that, in their mills, considerably less than the expected amount is selected.

The uniformity of the ore stream on entering the cutter is a large factor in the constancy of the fraction cut for sample. The mixing and retarding drums at the East Butte mill give an exceptionally uniform feed to the cutters and the fraction cut out is reported to be practically constant.

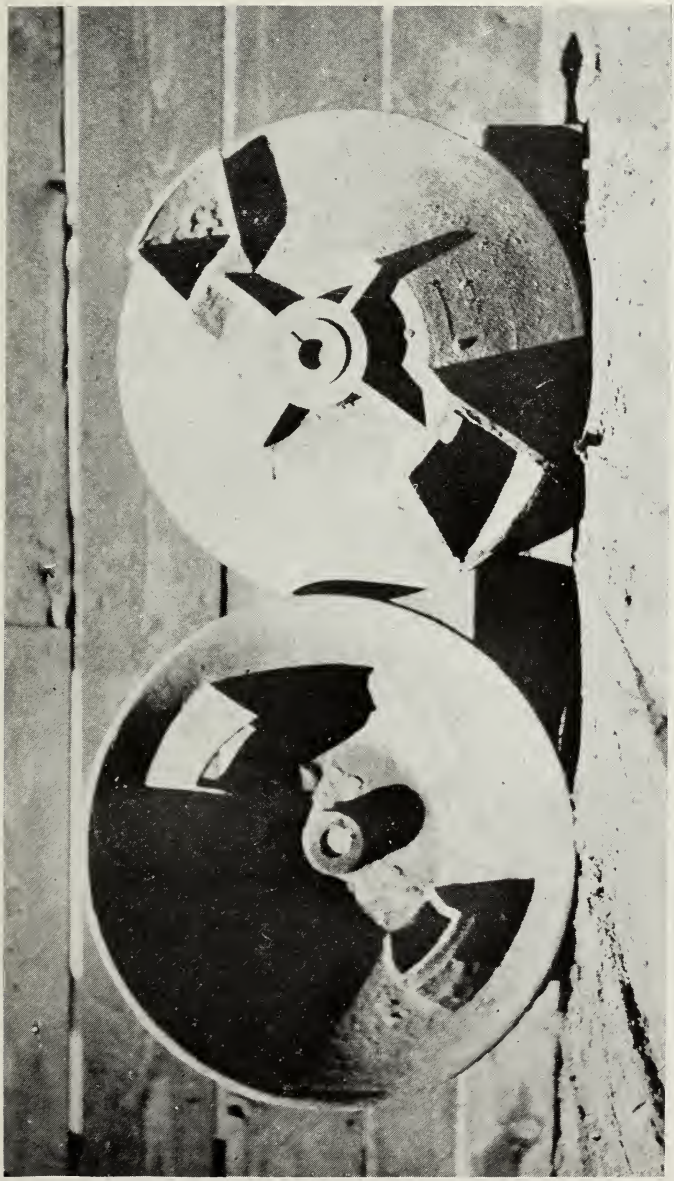


FIG. 15.—TWO-SLOT SNYDER SAMPLER.
The saucer rotates in a vertical plane.

A careful inspection of the relative sizes of cutter openings and ore pieces shows that the ratio of 4 is not often attained in the case of the first cutters. It is believed that attention to this detail will add to the perfection of future mills.

The number of cuts made by mechanical cutters is sometimes insufficient for accurate work, especially if the lot is hurried through the mill. The difficulty with speeding up cutters is the batting and scattering action on the larger pieces as the velocity of the machine increases. Many cutter designs are already on the market, but, if it should be found desirable to make more cuts in a unit time, it may not be too much to expect an improved design for high speed work.

MIXING MACHINES

Henry A. Vezin is commonly credited with first having used mixing and retarding drums in large scale sampling operations. He placed staggered baffles in the drums to mix the ore before it fell in a steady stream to the cutter below.

The mill of the East Butte Copper Mining Company, at Butte, Montana, has two mixing and retarding drums (see Figure 16) before the second and third cutters, respectively. Thus, as the first cutter is fed by the main ore stream, all three cutters are fed with a decidedly well-mixed and uniform stream of ore.

The other Montana mills depend largely on shaking feeders to mix and spread the samples, which one cutter delivers to the next. A revolving disk is, however, found in the No. 2 mill at East Helena, between two Vezin cutters; this feeder gives an especially uniform feed to the lower Vezin.

Retarding machines are highly desirable to elongate and equalize the ore stream after a cut has been made. Natural spreading in the short spouts does not give a smooth ore flow to either rolls or cutters. Synchromatic gaps and irregular fractions are naturally greatest when the stream equalization is least. Aside from the equalizing for rolls and cutter, any mixing of the material may be considered an incidental matter if the number of selections by each machine amounts to more than a thousand, and the values in the large and rich pieces do not exceed the limits for accuracy. The mixing of the ore stream is, however, an assurance of correct results if the number of cuts is reduced to only a few hundred.

It may not be out of place here to analyze just what happens on mixing a small lot of ore with the riffle cutter. We will suppose that a lot is poured over a 30-slot riffle with 50 shakings to and fro, the two halves are then united and the pouring repeated; the entire operation of cutting and uniting is continued until it has been done 10 times.

The slots divide the sample into 30x50, or 1,500 portions, at each pouring. The 1,500 portions are not superimposed but are spread out into 50 layers at each pouring; when the halves are joined the 50 layers from each side get superimposed, or, as may be said, each

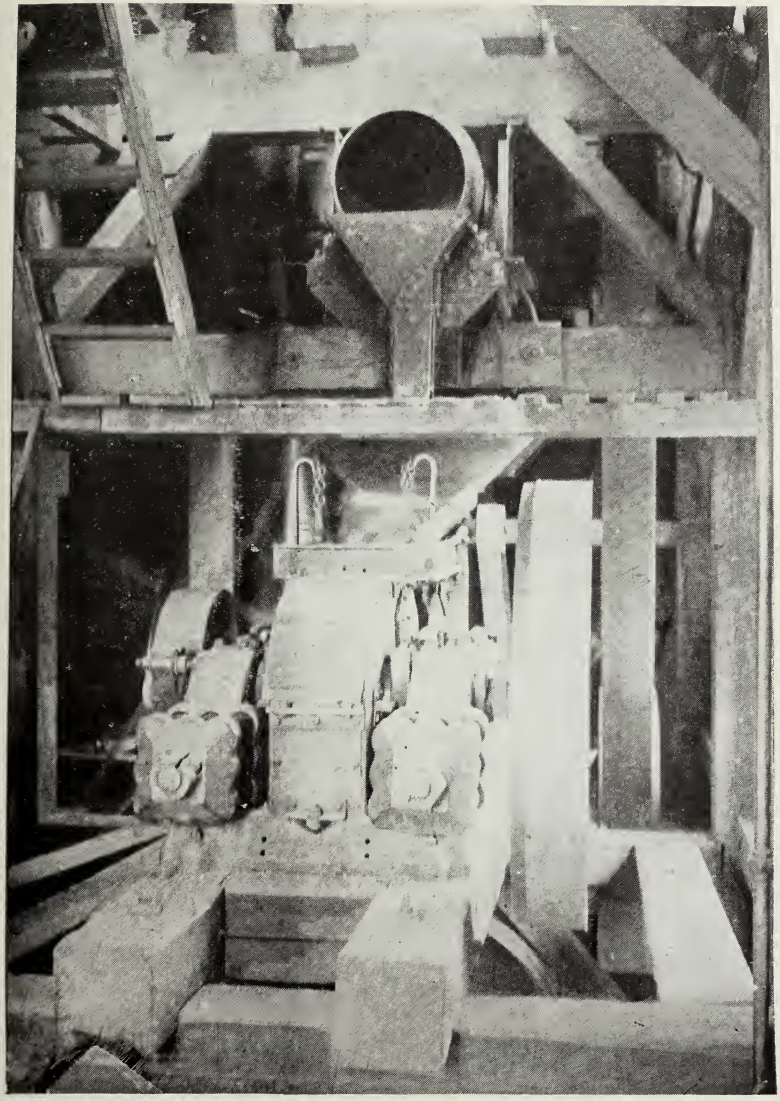


FIG. 16.—DRUM MIXER, SAMPLER, AND ROLLS IN EAST BUTTE MILL
This is the upper drum mixer, and the No. 2 sampler over the No. 2 rolls

pouring puts the material in 100 layers when the halves are united. On repeating the work 10 times the material clearly gets divided into 10x1,500 portions and the full numbers of layers increase to 10x100, or 1,000. The 100 layers made by the 1,500 portions at any one pouring give a splendid lateral distribution of any inequality, but cannot possibly equalize throughout the pulp any segregation in either the first, middle, or last of the lot poured. But uniting the halves and repeating does effectually dispense the vertical segregation, as the inequalities in the first, middle, or last of the pouring may be called. Thus, with a few repetitions, the lot becomes uniform laterally and vertically, or is well mixed. The previously described test on the quartz and iron ore is very good proof of the efficiency of riffle mixing.

DRYING MACHINES

It has already been mentioned that the Montana practice uses both steam and electrically heated cabinet shelf-dryers, as well as large steam tables. In all cases the operation is very simple and requires no attention. Although drying requires about the same time as mill sampling, it is, nevertheless, so rapid and simple that there is little incentive to speed up the process. Faster drying would inevitably demand higher and injurious temperatures, as well as moving parts to the drying apparatus. If all other essential operations in sampling were in as satisfactory a status as that of drying it would be fortunate, indeed.

SAMPLING OF TEST LOT BY STATE BUREAU

The results of resamplings and check samplings have been published from time to time, but to test the matter of sampling more exhaustively and at the same time provide tangible evidence that the custom mills in Montana are doing satisfactory work, the State Bureau acquired the use of a lot of ore and had it sampled at the three most important custom mills.

The carload weighed a little over 50 tons, and was from a Montana mine which is producing a silver-lead ore of considerably greater value than the average of the Butte mines. The ore was run-of-mine product and, like many high sulphide ores, more than half of it consisted of rather fine to earthy material. At least a quarter of the material was in lumps over two inches in diameter, and the rest was intermediate.

The minerals varied in size and texture from large pure grains to fine intimate mixtures. The mineral composition was, approximately:

Quartz	30%	Arsenical tetrahedrite (gray copper ore)	15%
Pyrite	25%		
Galena	15%	Zinc blende	5%

Other gangue minerals 10%

The lot typified Montana ore of the better sort, with commercial values in gold, silver, copper, and lead; an ore suitable for demonstrating the precision of sampling on customary and average materials.

The lot of ore was sampled twice at the Washoe Sampler, resulting in two independent final pulps. The lot was sampled in the No. 1 mill at East Helena, using the coarse by-pass; it was tenth-shovel sampled at East Helena, and then finally ground to pass the 2-mesh screens and again sampled in the No. 1 mill, this time in the ordinary way. The lot was sampled once at the East Butte mill while in the coarse condition, but duplicate portions were taken from the mill product before fine grinding.

Six different samplings were thus made, giving seven pulps; three different types of mechanical cutters were used and once the lot was hand-sampled. The hand-sampling was first by the tenth-shovel method, and it was then coned and quartered until the final splitting for packets was made with a table riffle.

The actual sampling time at the different mills varied; at the Washoe Sampler the lot required 20 and 30 minutes at each respective sampling; at the East Butte mill 50 minutes were required for the sampling; at East Helena fully 2 hours were taken each time the lot was run through the mill.

The final sampling at East Helena, after crushing to half-inch size, afforded a good standard test, since the material was then all in small sizes, had undergone repeated dispersions and retardations in the mills, and was cut at least 3,500 times by each of the mill samplers.

The lot was sampled in the presence of the author in each instance; no particular arrangements were made at the mills, nor was the sampling carried out in any way differently from the routine procedure which the author has repeatedly observed when he has happened into the mills.

The seven final pulps were analyzed under as nearly identical conditions as possible in the State School of Mines laboratories. Lest too few results might involve deviations in the chemical work instead of in the sampling, the analyses were checked over from 6 to 8 times so as to furnish average figures for each component. Pulp inequalities, chemical influences, and manipulations all introduce deviations, which repeated analyses alone can eliminate so as to show the precision or lack of precision in the sampling.

The results of the analytical work follow:

Sample	Silver, oz. per ton	Gold, oz. per ton	Lead, per cent.	Copper, per cent.	Iron, per cent.	Insoluble, per cent.
A	37.8	.21	12.73	1.74	14.49	32.58
B	37.3	.22	12.46	1.69	14.43	33.07
C	37.0	.23	12.50	1.74	14.46	32.87
D	37.9	.21	12.64	1.78	14.77	32.01
E	37.3	.21	12.64	1.76	14.52	32.83
F	37.4	.21	12.72	1.70	14.35	32.50
G	37.5	.22	12.91	1.73	14.72	32.22

One conclusion, only, can be drawn from the results in the table: namely, that the sampling was well done in each instance. The difference between the several pulps is less than excellent analysts might report on one and the same pulp.

The individual items and gross values of the lot may be calculated for each sampling, reckoning silver at $1.25 an ounce, gold at $20.67 an ounce, lead at 8 cents a pound, and copper at 18 cents a pound.

Sample	Silver	Gold	Lead	Copper	Total	Deviation From Mean
A	$47.25	$4.34	$20.37	$6.26	$78.22	$0.44
B	46.62	4.55	19.94	6.08	77.20	0.58
C	46.25	4.75	20.00	6.26	77.26	0.52
D	47.38	4.34	20.22	6.41	78.35	0.57
E	46.63	4.34	20.22	6.34	77.52	0.26
F	46.75	4.34	20.35	6.12	77.56	0.22
G	46.88	4.55	20.66	6.23	78.32	0.54

The total values range from $77.20 to $78.35, an extreme difference of $1.15; the average deviation from the mean of all the totals is $0.45. Ore producers should certainly be well satisfied with custom sampling which shows this degree of precision.

MILL FLOW SHEETS

To indicate the treatment by which each of the samples was obtained in the State Bureau test, the following flow sheets have been prepared.

Washoe Sampler—

Cars unloaded over hopper; 18'x20'x11' deep
Shaking grizzly feeder; 1.5"x2.0" holes in 24"x20" section
Crusher; 20"x10" opening
Shaking tray
Elevator to top of mill
No. 1 cutter; Brunton oscillatory, 7.0"x10.5" opening, 40 cuts per minute
Sample; 20%, or 20,000 lbs. on 50-ton lot
Shaking tray; 12" effective length
No 1 rolls; 16"x36"
No 2 cutter; Brunton oscillatory, 6.0"x8.0" opening, 28 cuts per minute.

Sample; 20%, or 4,000 lbs. on 50-ton lot
Shaking tray; 9" effective length
No. 2 rolls; 14"x30"
No. 3 cutter; Brunton oscillatory, 4.5"x6.75" opening, 63 cuts per minute

Sample; 20%, or 800 lbs. on 50-ton lot
Bell distributor
No. 3 rolls; 12" x 24"
No 4 cutter; Brunton oscillatory, 3.5"x5.0" opening, 68 cuts per minute.

Sample; 160 lbs. on 50-ton lot
Trolley bucket
Steel sampling floor in bucking room
Split shovel to 8 to 10 lbs.

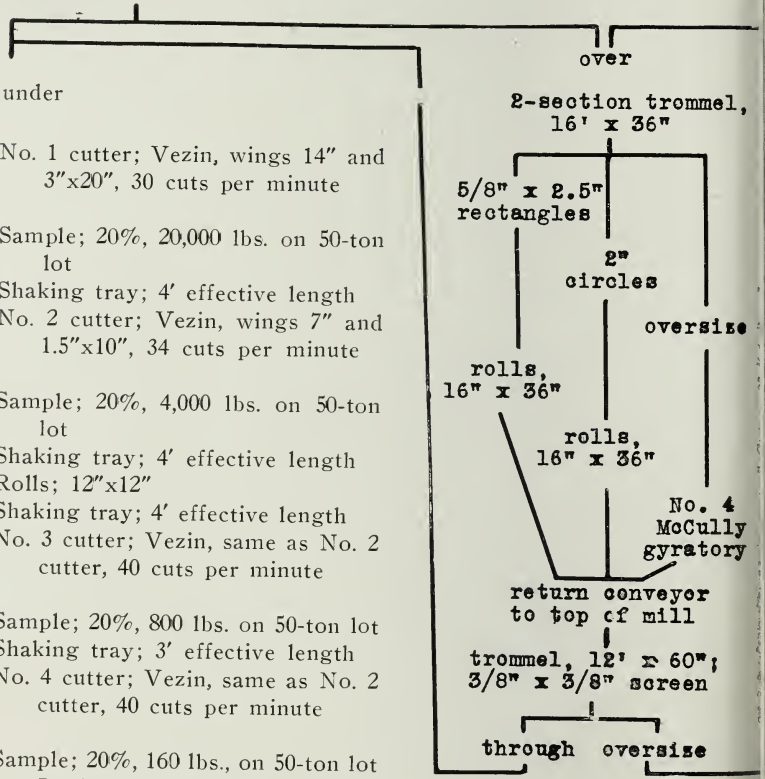
Sample; 8 to 10 lbs.
Dried in shelf cabinet, electric heat
Engelbach grinder
Riffle cutter; 26 slots, each .64"x2.0"

Sample; 32 ounces
Braun disk grinder
Hand sieves; 100, 120, 150, and 200 mesh
Rolled on pebble-surfaced oil cloth 1,000 times
Sample split for 4 packets with inclined riffles

East Helena No. 1 Mill—

Cars unloaded onto steel pan conveyor; pans 18"x18"x6"
Chute to No. 5 McCully gyratory crusher
Belt conveyor, 16" belt, to top of mill, under magnet
Chute to

A (fine grinding and sampling)
Trommels; 12'x60", ⅜"x⅜" mesh



No. 1 cutter; Vezin, wings 14" and 3"x20", 30 cuts per minute

Sample; 20%, 20,000 lbs. on 50-ton lot
Shaking tray; 4' effective length
No. 2 cutter; Vezin, wings 7" and 1.5"x10", 34 cuts per minute

Sample; 20%, 4,000 lbs. on 50-ton lot
Shaking tray; 4' effective length
Rolls; 12"x12"
Shaking tray; 4' effective length
No. 3 cutter; Vezin, same as No. 2 cutter, 40 cuts per minute

Sample; 20%, 800 lbs. on 50-ton lot
Shaking tray; 3' effective length
No. 4 cutter; Vezin, same as No. 2 cutter, 40 cuts per minute

Sample; 20%, 160 lbs., on 50-ton lot
Locked sample hopper

Sample; wheelbarrow to steel sample floor in or near bucking room
Cone and quarter, or riffle cut, to 10 to 12 lbs.
Dried in shelf cabinet or on steam table
Bell grinder
Hand sieves; 100, 120, and 150 mesh
Table riffle to 24 ounces
Rolled 15 minutes on special paper
Sample split with table riffle to 4, 6-oz. packets

B (coarse sampling)
No. 1 Vezin cutter

Sample; 20% Discard, out of mill on conveyor
Return conveyor to top of mill
Chute to No. 2 trommel, 12'x60", ⅜"x⅜" mesh

under over
No. 2 Vezin cutter 2-section trommel and closed circuit, as above

Same as under A to finished sample

East Butte Sampling Mill—

Cars unloaded over mill hopper
Shaking feeder
Crusher; 12"x24" opening
Spout to elevator
Elevator to top of mill
No. 1 cutter; East Butte, 8"x12" openings, 28 cuts per minute

Sample; 10%, 5 tons on 50-ton lot
Shaking tray; 3' effective length
No. 1 rolls; 16"x36"
Drum mixer; 6'x2', 16 r.m.p.
No. 2 cutter; East Butte, 6"x7.75" openings, 26 cuts per minute
Sample; 10%, 1,000 lbs. on 50-ton lot
Shaking tray; 3' effective length
No 2 rolls; 10"x24"
Drum mixer; 5'x23", 10 r.p.m.
No. 3 cutter; East Butte, 4.5"x5.5" openings, 16 cuts per minute

Sample; 10%, 100 lbs. on 50-ton lot
Shaking tray; 3' effective length
No. 3 rolls; 9"x9"
Sample can
Cast iron riffle cutter to 15 to 20 lbs.

Sample; 15 to 20 lbs. to bucking room
Riffle cutter to 8 to 10 lbs.
Sample to shelf cabinet or table dryer
Bell grinder
Table riffle to 16 ounces
Hand sieves, 100, 120 and 150-mesh
Rolled on cloth
Table riffle; split to 4, 4-oz. packets

SAMPLING MILLS IN MONTANA

THE WASHOE SAMPLER

The $150,000 steel-concrete custom ore sampling plant of the Anaconda Mining Company is known as the Washoe Sampler and is situated on the main line of the Butte, Anaconda, and Pacific Railroad at Butte, Montana. The main mill portion is absolutely fireproof; it was put in operation in 1911, after a fire had destroyed the previous structure. The new mill was designed and built by the company engineers following the Taylor and Brunton system, which had been successfully demonstrated in the first mill.

Figure 17 is a diagram of the Taylor and Brunton system, which, in a general way, is the scheme followed in the present sampler. The Brunton oscillatory time samplers are, of course, the cutters installed. The types of machines used and the fractions cut at the several stages have already been indicated in the flow sheet of the mill, and are repeated in Figure 17. The main machinery tower has floors 35 feet by 45 feet; the main elevator pit floor is 28 feet below the ground floor, and the ridge of the building is 68 feet above, a total elevation of 96 feet thus being used.

The arrangement of the mechanical, power, and switching facilities is such that 500 tons of ore can be sampled in an 8-hour shift, and 1,200 tons can be put through in 24 hours. A 50-ton lot has been sampled in 9 minutes, but the usual running time is from 20 to 30 minutes; if ore comes in box cars the sampling depends on how long the unloading takes.

Figure 18 shows a portion of the tracks serving the plant. After weighing on the upper set of Fairbanks 100-ton recording beam scales, the cars are lowered by cable to the right hand side of the mill and unloaded in the shed over the mill hopper. As soon as a car is unloaded it can be pulled back with the electric hoist and let down on the left side of the mill to receive the same lot of ore it originally contained. On the loading side of the mill is a second scale; cars can thus be switched from one side of the mill to the other in a minute or two. They can be weighed after loading and then let down farther on the same track for delivery to the railroad.

A wagon and truck unloading shed is seen at the right in Figure 18; below the floor of the shed are fourteen 50-ton hoppers over a conveyor which delivers to the mill hopper. The brick structure seen between the tracks in the foreground of Figure 18 houses the blacksmith shop and change room. Figure 19 shows how massive cast iron pipe may be used for permanent and tight spouting in mill equipment.

The mill normally selects 0.16% of the original lot for the bucking room; by using a special cam arrangement in the mechanism of the second cutter only 0.04% need be cut out. The smaller cut is convenient on large lots. Four cutters will be used on lots weighing between

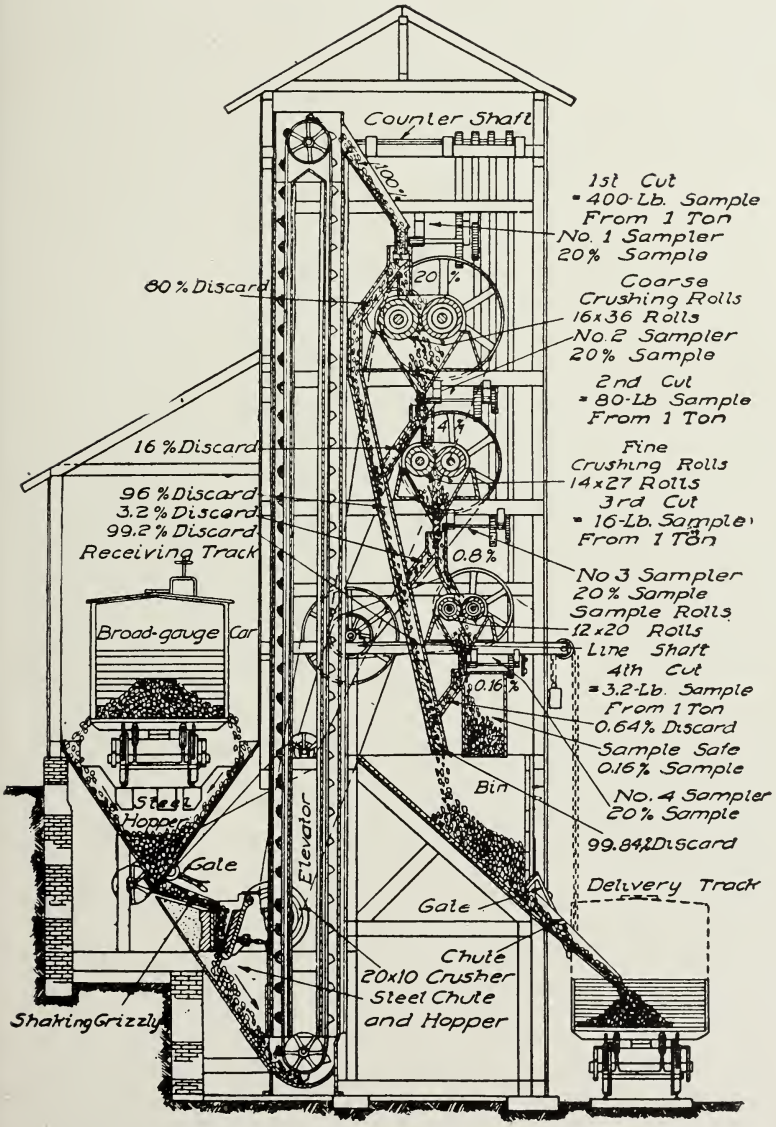


FIG. 17.—TAYLOR AND BRUNTON SAMPLING SYSTEM.

The Washoe Sampler follows this general diagram closely.

(After Brunton, Trans. Am. Inst. Min. Engrs., 1909)

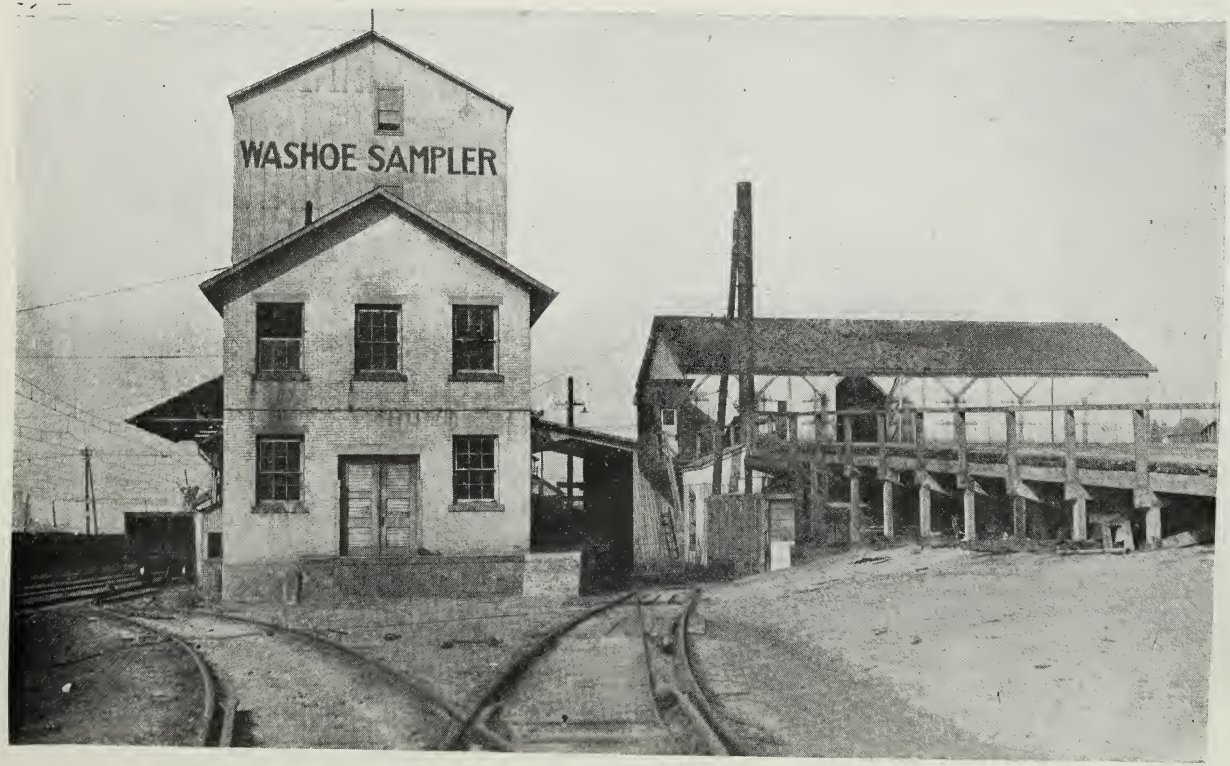


FIG. 18.—VIEW OF WASHOE SAMPLER FROM THE EAST.

A car of ore is unloading in the shed at the right of the sampler, and another is loading out on the left side. The change room is over the blacksmith shop in the brick structure.

50 and 12.5 tons. Smaller lots require less cutters in the following gradations: on lots weighing from 25,000 pounds down to 5,000 pounds three cutters are used, on lots weighing from 5,000 pounds down to 1,000 pounds two cutters are used, and on lots weighing less than 1,000 pounds only one cutter is used. The 1/40th of the entire lot, which must be held 30 days according to the Montana law, is usually the reject from the third cutter on large lots; with smaller lots it may be the reject from the fourth cutter or even the entire lot itself.

The frontispiece shows that the whole front section of the mill is merely a row of 50-ton steel bins; these bins are, of course, available for storing large lots whenever necessary. Beneath the large bins are 48 small bins on the ground floor of the mill, which are in continual use for storing the 1/40th portions. When the legal period has elapsed, the reserve bins are emptied in groups and a composite lot is run through the mill and then sent to the smelter. Superintendent Margetts states that the reserve samples are very rarely called into service; whenever one is used particular attention is given to properly cutting down the entire sample in the presence of the shipper. The shipper is never allowed to take a small grab sample for control assay. When the reserve samples are properly worked down to the final packets, in the same manner as the original sample was, the assay results prectically always check the first assaying. Only in the rarest instances is a complaint carried further.

The tendency to increase the fineness of grinding has been marked in the case of the Washoe bucking room. The 80-mesh sieve once used has been entirely discarded. Copper ores are ground to pass 100-mesh, silver ores are ground to pass 120-mesh, high-silver ores, lead ores, and zinc ores are ground to pass 150-mesh, and high-gold ores to pass 200-mesh. The mill experience has been that lead and zinc ores, as well as the rich gold ores, require the finer grinding for satisfactory chemical results on the pulps. If gold metallics are encountered they are ground with some of the pulp on the bucking board until everything passes the screen. Local experience is that metallics in ores tributary to the Anaconda smeltery easily yield to disintegration when ground with sample pulp; after rolling on the cloth the metallics become uniformly dispersed throughout entire pulp.

THE SAMPLING MILLS OF THE AMERICAN SMELTING & REFINING COMPANY AT EAST HELENA, MONTANA

The American Smelting & Refining Company provides extensive sampling facilities for the custom ores which maintain its lead smeltery at East Helena, Montana. The smeltery started operations just 30 years ago, and some of the sampling mill construction dates from about that time, although many improvements and large additions have been made meanwhile. The plant maintains three distinct sampling mills and a steel sampling floor, 55 feet by 65 feet in the clear, for cone and quarter sampling.

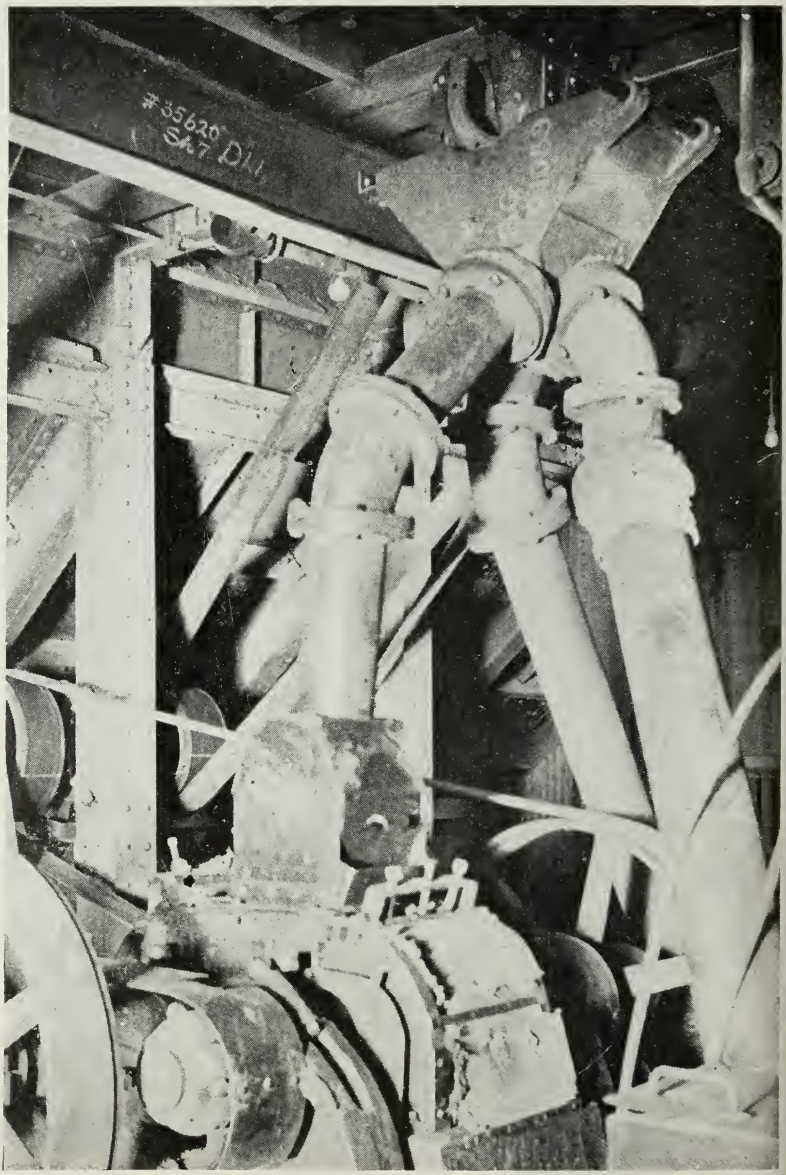


FIG. 19.—THIRD SAMPLER AND THIRD ROLLS IN WASHOE SAMPLER

This set of rolls has the bell distributor inside the housing over the rolls. The pipe at the back of the cutter carries reserve sample to the trolley bucket on the first floor.

The East Helena practice largely demands grinding ores and flux to pass 3/8-inch mesh to meet the roasting requirements. The company has, accordingly, fitted both the No. 1 and No. 2 sulphide mills to crush to this fineness and then to make the sample selections. The fine-grinding not only accounts for the peculiar flow sheet of the No. 1 and No. 2 mills, but consolidates the cutters in small space and assures highly satisfactory mechanical division for sample. The No. 1 mill has provision for either grinding the entire lot to pass the 3/8-inch mesh trommels before sampling, or, after the preliminary crushing in the big gyratory, 1/5th of the lot may be cut out with the first sampler and then reduced to pass the 3/8-inch screen on its way to the last three samplers. The No. 2 mill is also for sulphide ores and furnace products; it has no by-passes in its closed circuit, which grinds to pass a 5/16x3/8-inch screen before sampling with two machines in close series. Both the No. 1 and No. 2 mills are provided with excellent models of the Vezin sampler. The No. 3 mill is for oxide ores and has Brunton vibratory cutters. The No. 1 mill delivers 1/625th of the lot as sample; both of the other mills deliver 1/25th of the lot as sample.

The No. 1 mill is conspicuous in that it contains no elevators; the transfer and elevation of materials is entirely by conveyor, of which there are five in use. The steel pan conveyor, onto which all incoming ores are unloaded, is well indicated in Figure 20. It will be noticed that the conveyor rises at the far end; Figure 21 makes the nature of this rise apparent, for in this cut one sees that the conveyor enters the building which contains the No. 5 McCully gyratory. After passing the gyratory, the ore goes up the long incline to the top of the main mill building. The main building covers a space 63 by 30 feet; the structure is steel and concrete and houses the equipment which has been indicated in the flow sheet of the mill on page 44. Figure 22 is a picture taken on the ground floor of the mill; the two 16x36-inch rolls and the No. 4 McCully gyratory are seen from left to right in the foreground, and the sample cabinet is farther back to the left. The first Vezin is on the second floor above the cabinet, and the three Vezin samplers following are in this cabinet on the ground floor. The two upper drawings of Figure 23 indicate the dimensions, the configuration, and the spout approach to the Vezin samplers in the No. 1 mill. The first Vezin makes 30 sample cuts a minute, the second makes 34 a minute, and the last two make 40 cuts a minute.

The No. 2 mill is a massively-built wooden structure, with floor dimensions 63x36 feet, built to crush sulphide materials to pass 5/16x3/8-inch rectangles before sampling with two Vezin samplers in tandem. After the mill feed passes the crusher, whose opening is 9 by 15 inches, the material is elevated and dropped to a 14x27-inch set of rolls. The material is again raised and enters the trommel with 5/16x3/8-inch openings, from which the undersize falls to the Vezin samplers and the oversize to a set of 14x26-inch rolls in a closed circuit with the trommel. The upper Vezin makes 35 sample cuts a

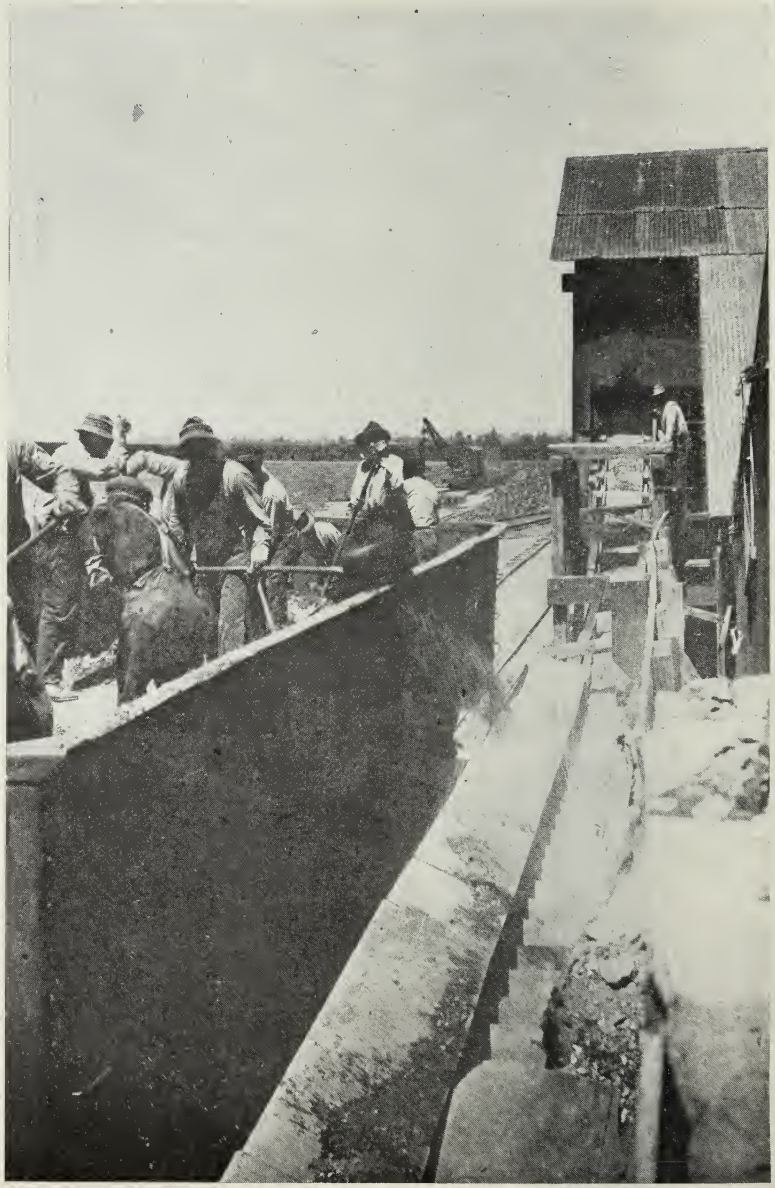


FIG. 20.—UNLOADING ORE AT EAST HELENA NO. 1 MILL.

Steel pan conveyor delivers to the No. 5 McCully gyratory in the shed.

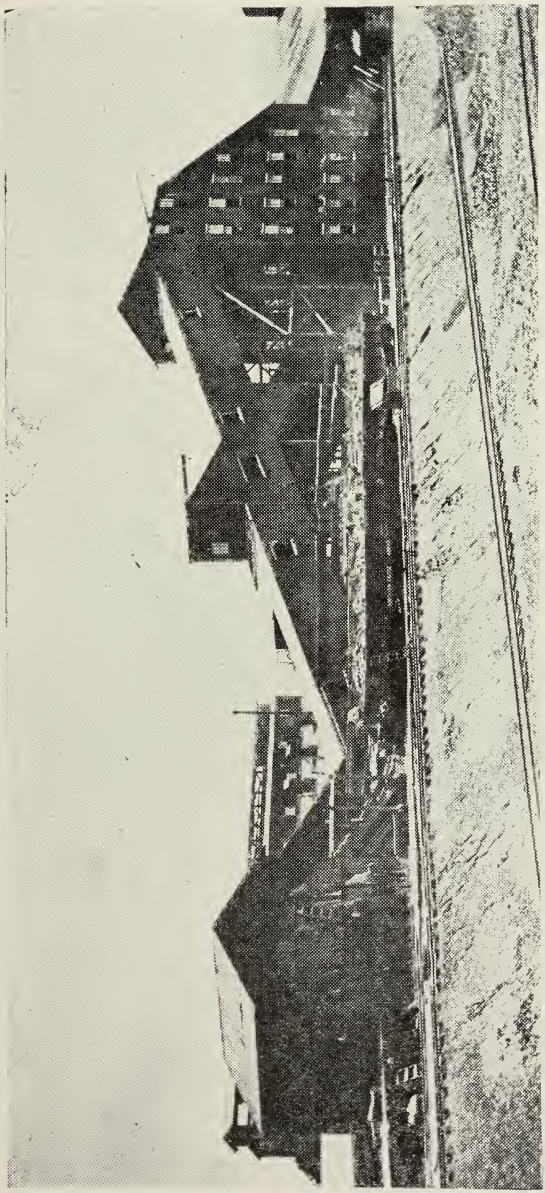


FIG. 21.—SAMPLING MILL NO. 1 AT EAST HELENA.

Men are unloading limestone flux onto the conveyor to the coarse crushing shed.

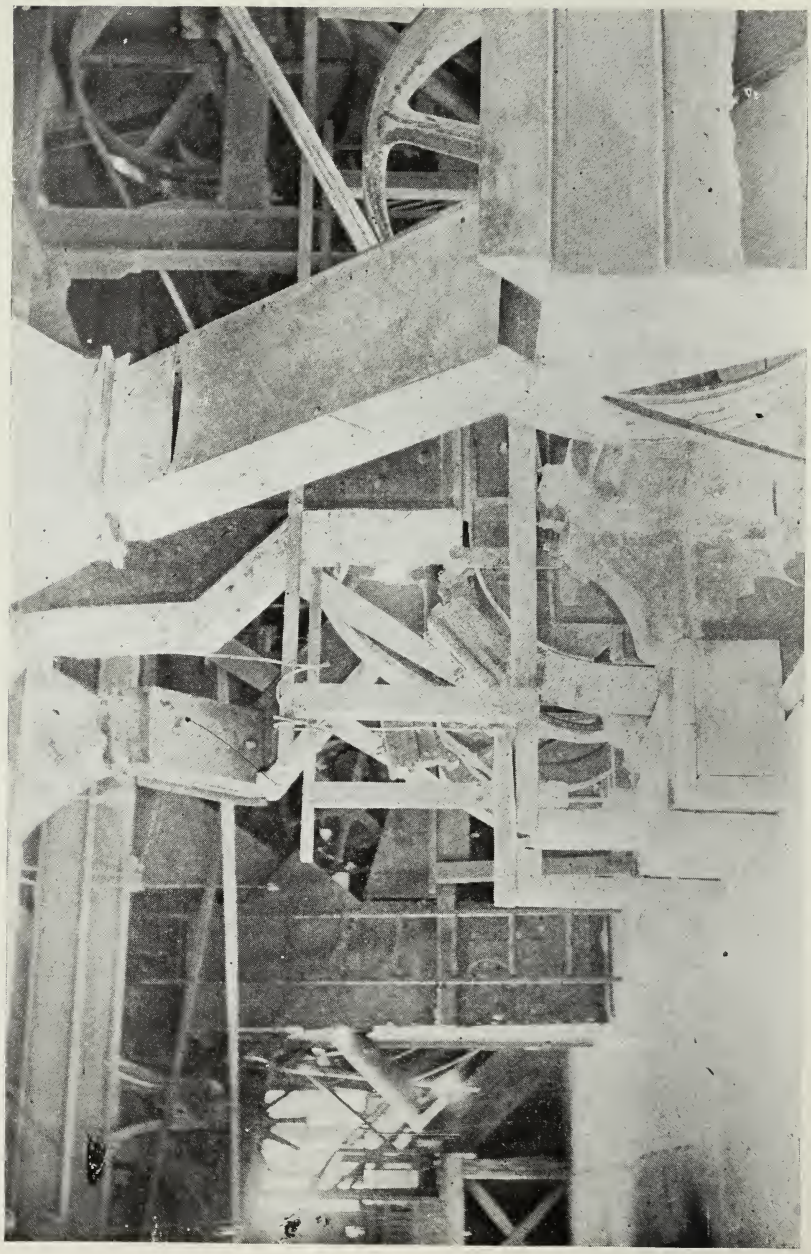


FIG. 22.—FIRST FLOOR EQUIPMENT AT EAST HELENA NO. 1 MILL.

The three-hoppered spouts from the trommel on the floor above lead oversize to the flume

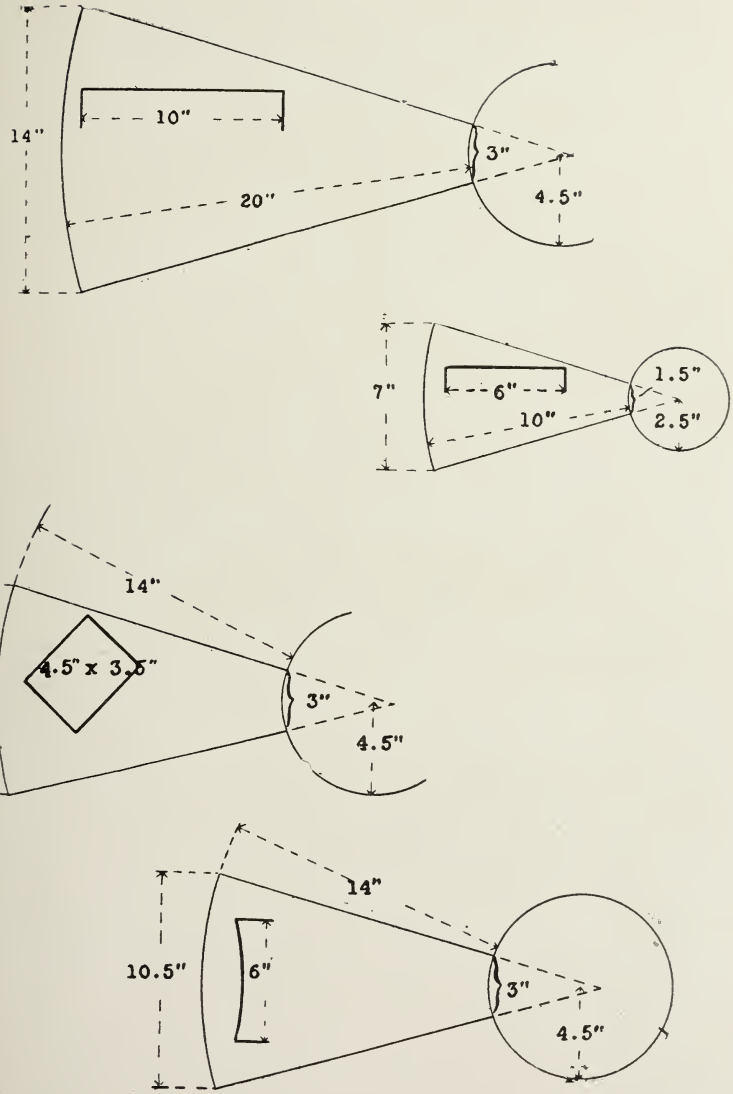
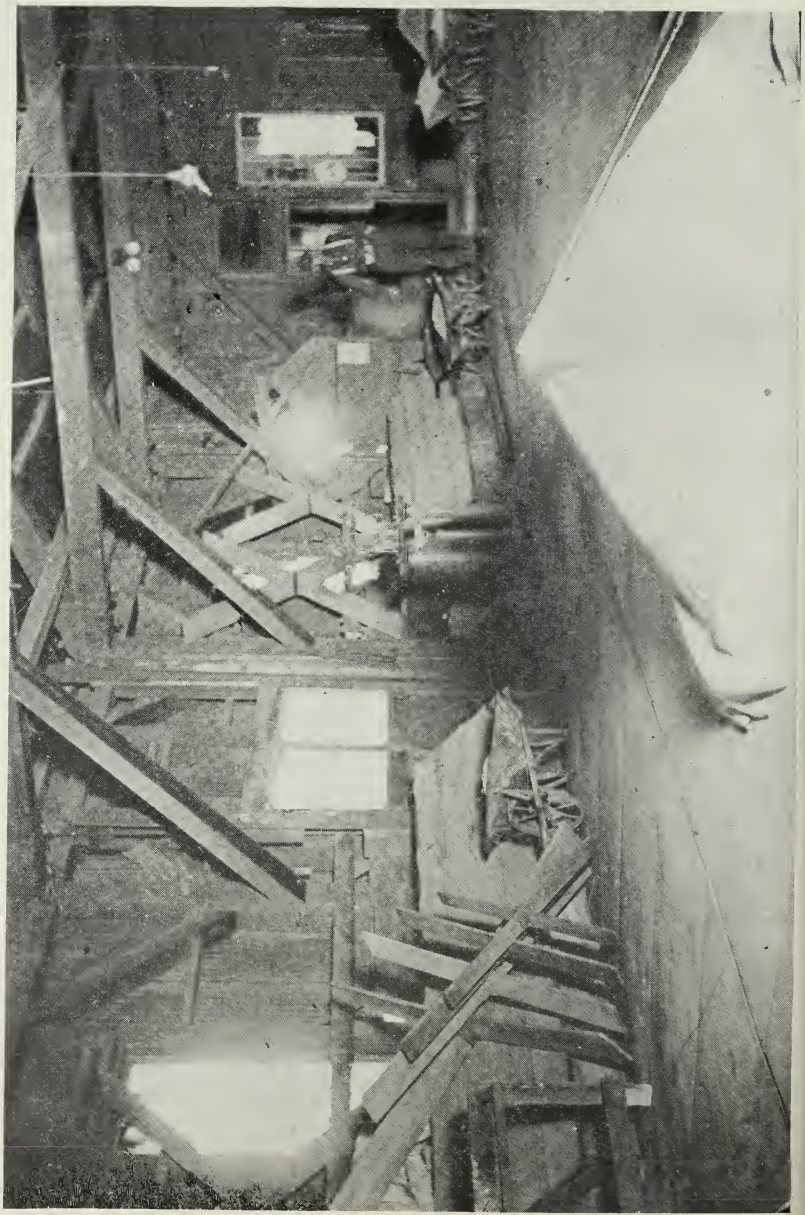


FIG. 23.—VEZIN SAMPLER WINGS AT EAST HELENA SAMPLING MILLS.

The two upper drawings are of the cutter wings in the No. 1 mill; the two lower drawings are of the wings of the tandem cutters in the No. 2 mill. The measurements were taken from the machines and show satisfactory design.



minute and discharges onto a slowly rotating circular plate feeder, which pushes out a uniform stream to the Vezin below. The second Vezin makes 60 sample cuts a minute.

The oxide, or No. 3 sample mill, is a small machinery tower at one side of the large steel sampling floor adjacent to the No. 2 sample mill. The oxide mill is provided with two jaw crushers, a set of rolls and No. 2 and No. 3 Brunton vibratory cutters. One-fifth of the original lot is delivered as sample.

The steel sampling floor has a set of platform scales, a 10x7-inch crusher and a 12x12-inch rolls. Screens are provided for breaking up lumpy ores and numerous crosses allow several hand-sampling operations to take place simultaneously. Figure 24 is a view along one side of the steel floor; a cone of ore covered with canvas is in the foreground, wooden crosses are along the wall, while around the entire room is a row of covered bins to store the reserve samples. The mills are provided with 58 wooden reserve bins similar to those in Figure 24, and near the No. 1 mill is a group of 42 steel pockets for the same purpose.

The East Helena mills are provided with commodious fine-grinding and finishing facilities. The bucking room is 27x57 feet; it has an all-steel floor and the following pieces of equipment:

One Sturtevant, 3″x8″, roll jaw crusher
One F. M. Davis, 12″x20″, rolls
Two steam drying tables, each 30″x72″
Two Engelbach type, fine grinders
Three steel bucking boards
One round steel table, 5′ diameter
One cabinet shelf dryer, 12 double shelves
Two stand riffle cutters, 26, 5/8″ slots each
Two table riffle cutters, 36, 5/16″ slots each.

The bucking room, as well as each of the mills, is, of course, provided with pressure air for cleaning. Ores are commonly ground to pass 100-mesh, high-silver ores to pass 120-mesh, and gold ores to pass 150-mesh. Ground and sieved samples are rolled on a special black surfaced paper before cutting for the final packets with a table riffle.

THE EAST BUTTE COPPER MINING COMPANY'S SAMPLING MILL

The East Butte Copper Mining Company samples all of its second-class ore and custom ore in a mill adjacent to its smeltery at Butte, Montana.

The mill building is a wooden structure some four stories high, with a main sampling section 33 feet long and 18 feet wide. The crusher is under the hopper, over which the elevated track passes beside the mill. The crushed ore is elevated to the first sampler,

FIG. 25.—EAST BUTTE SAMPLING MILL.

Lots of ore are received over the "high line" above the bins to the left. Outgoing cars may be loaded on the receiving line or from pockets over the depressed track at the right.

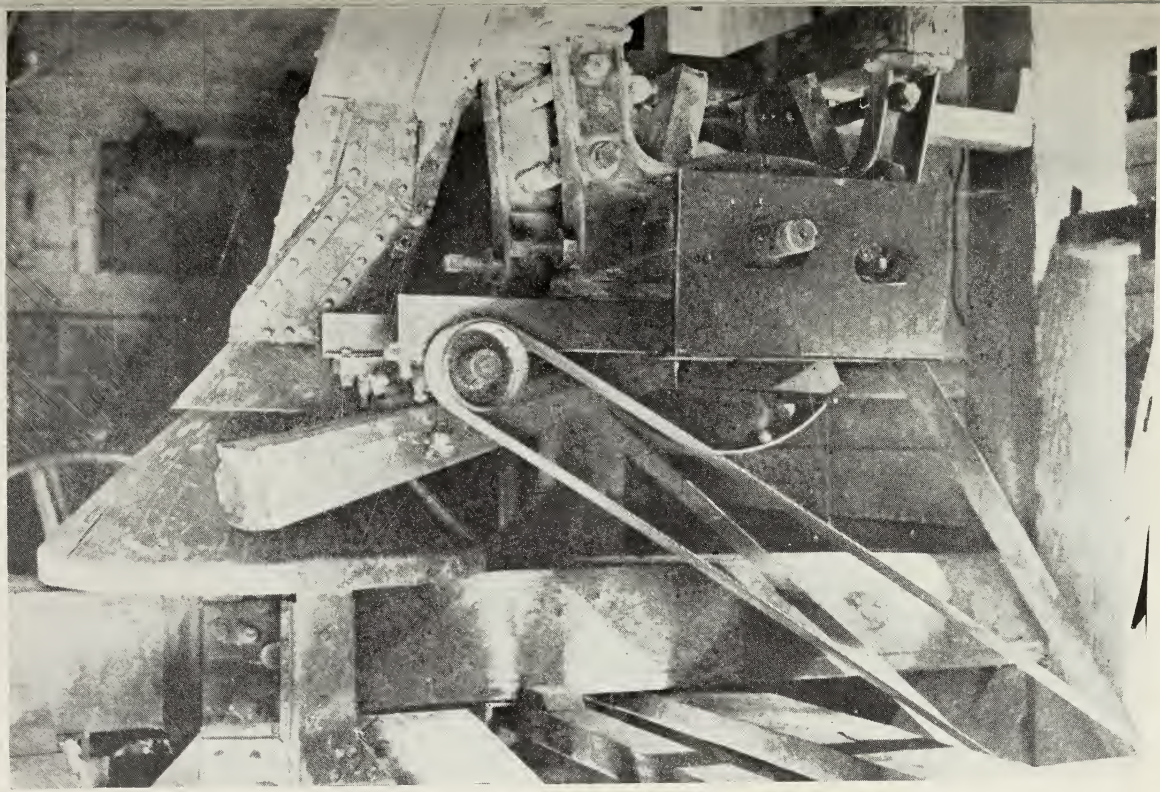


FIG. 26.—THIRD SAMPLER AND THIRD ROLLS IN EAST BUTTE SAMPLER.

The sample can is placed directly under the rolls. Notice the vertical spout to the sample saucer, and the long shaking trough from the sampler to the rolls.

which is in the top of the mill over the bin section which adjoins the main machinery section of the structure. A conveyor over the bins extends along the more elevated part of the building and allows sampled ore to be dropped in any one of the series of bins, to be sent back to cars on the high unloading line, or to be screened, and crushed, and dropped in special bins. Figure 25 shows the main machinery sections in the center of the picture; behind and to the right is the bin compartment, which is a story higher and has the series of spouts to load cars on the depressed track. The unloading line and mill hopper are under the roof at the left of the picture.

The cutters used in the mill have already been described as the East Butte type, and the mill flow sheet has been indicated on page 45. The large cast iron stand cutter used to finish the mill samples ready for the bucking room, is a prominent piece of equipment; it is the largest and most substantial riffle cutter in use at any of the sampling mills. Figure 16 gives an excellent idea of the drum mixers and the way they are placed over the samplers. The final sampler is pictured in Figure 26, where it is seen suspended between the spout from the last drum mixer and the shaking trough feeding the last set of rolls.

A peculiar method is used in this mill for handling the sampler rejects. The reject from the first sampler, which is in the top of the mill under the dump of the single elevator, is run to final disposal as the lot is sampled. The rejects from the second and third cutters drop to a hoppered bin under the first floor, from whence, after the entire lot is sampled, they are conveyed to the elevator and follow the rest of the lot to its final disposal.

Compressed air is used for cleaning. The bucking room contains the usual equipment for fine grinding, drying, mixing, and dividing.

THE SAMPLING MILLS AT ANACONDA, MONTANA

The Anaconda Copper Mining Company maintains two sampling mills in its great smeltery at Anaconda, Montana. The mills are almost exclusively used for sampling ores from its own mines, since custom ores are sampled in the Washoe Sampler at Butte.

Figure 27 shows the huge main double sampler. It is probably the largest sampling mill in the world, having an 8-hour capacity of 2,000 tons. The mill is constructed and operated in two entirely independent but identical units. Most of the ore handled comes from the Butte mines and averages about 3.2% copper, 2.5 ozs. silver, and 0.01 oz. gold. As the ore runs fairly uniform, the cut-offs between lots are indistinct, and the cleaning of equipment between lots, which is a very important feature in all the other mills, is dispensed with.

The Anaconda mill is of frame construction, with a sprinkler system for fire protection. The floor section is 45 feet by 63 feet; there are four floors and a small basement under the crushers. The general mill scheme is given in Figure 28, which correctly represents

FIG. 27.—THE ANACONDA SAMPLING MILL.
—Photograph by Baker, A. C. M. Co.

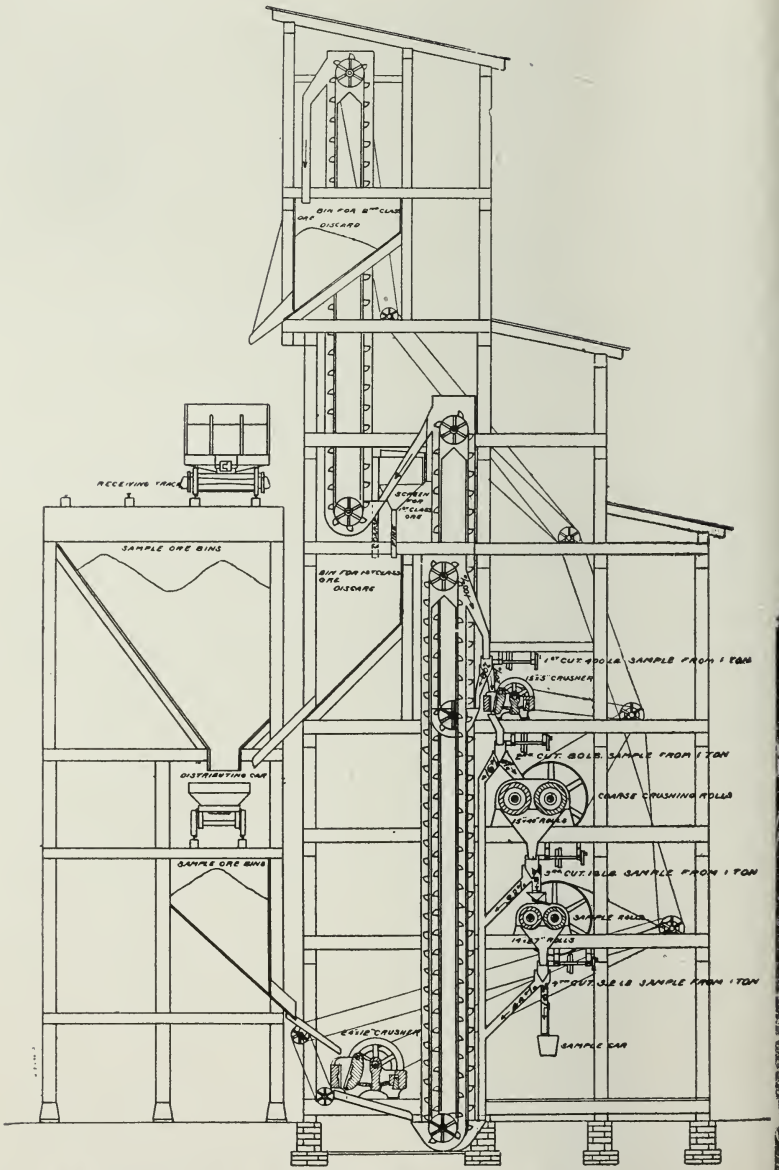


FIG. 28.—DIAGRAM OF ANACONDA SAMPLING MILL.
(Courtesy of A. C. M. Co.)

The uppermost elevators now deliver to conveyors carrying to bins across the tracks.

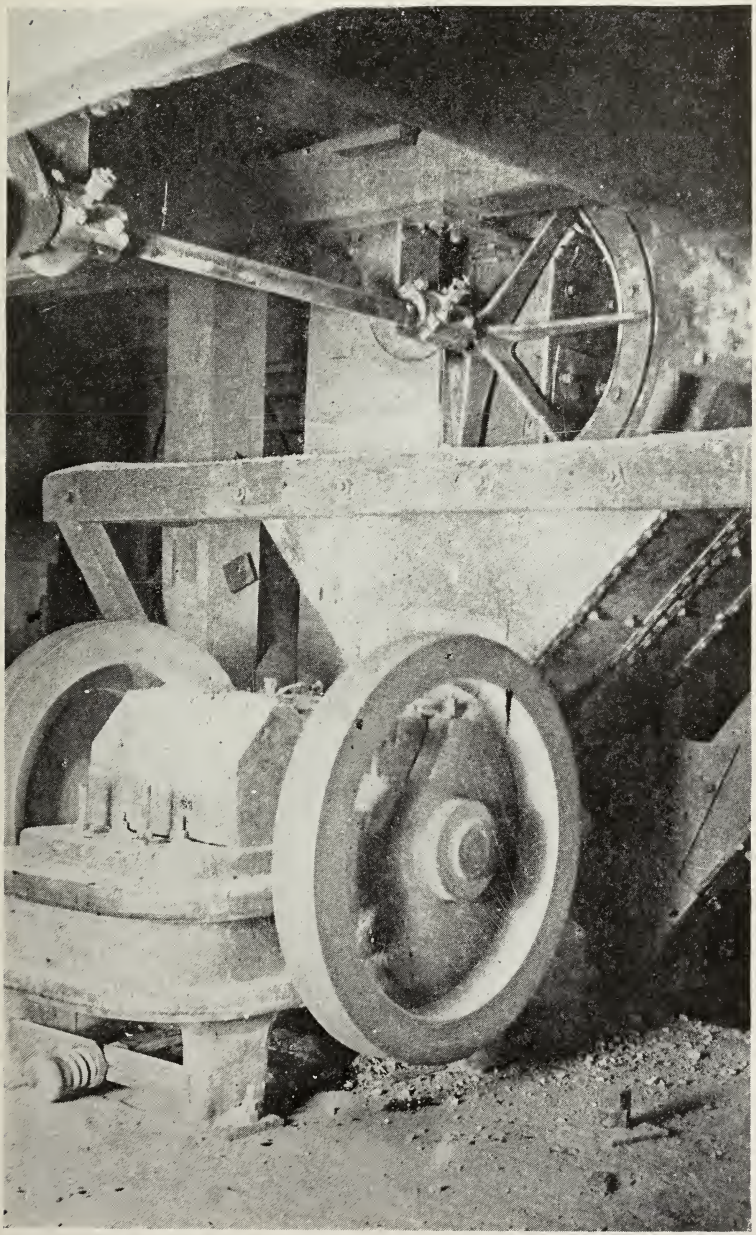


FIG. 29.—FIRST SAMPLER AND SECOND CRUSHER IN ANACONDA MILL.

The sampler is placed close to the crusher. The oscillator has a diameter of nearly six feet, which makes it by far the largest cutter in the State.

all but the more recent conveyors from the top of the mill across the tracks to the spouts delivering to the concentrator feed bins.

The equipment is characterized by its large size and close spacing of cutters over the next lower crushing machine. The latter feature is well indicated in Figure 29, which shows one of the first Bruntons over its 8x18-inch crusher. The mill also has a partial dust-collecting system with suction intakes at the most dusty points, and a cyclone separator outside the building.

The bucking room is equipped with the following units in duplicate:

Engelbach grinders
Braun disk grinders
Bucking boards
Stand cutters; 26 slot
Table riffles; 16 slot
Power (air) screens
Cube mixers; 8" sides

Figure 30 is a splendid picture of the bucking room and its equipment. A 15-horsepower motor drives the equipment, while another small motor in the far corner is coupled to a fan which exhausts the hood above the two Engelbach grinders and delivers the dust outside of the building. The room beyond, which is just through the double doors seen in Figure 30, contains the steel floor for split shovel work, a 10 by 4-inch jaw crusher, moisture scales, and a large steam drying cabinet.

The Southern Cross sampling mill is a plant addition made to the smeltery some three years ago by the company. The mill covers an area 25 by 48 feet, and has four floor levels; it is placed between two columns and under the "high line," which tracks lead to the main sampling mill and the concentrator bins. The mill has been used only for sampling Southern Cross gold ore, which was not conveniently sampled in any other way.

The crushing of the ore is done entirely by jaw crushers. The cutters are of special design; they have a wing much like the Vezin wing, but oscillate back and forth in a horizontal plane by means of a gear-and-crank mechanism.

The Southern Cross mill is sprinklered for fire protection; it is cleaned with compressed air, as other mills. It has its own bucking room equipped much as the larger Anaconda mill, but with single units.

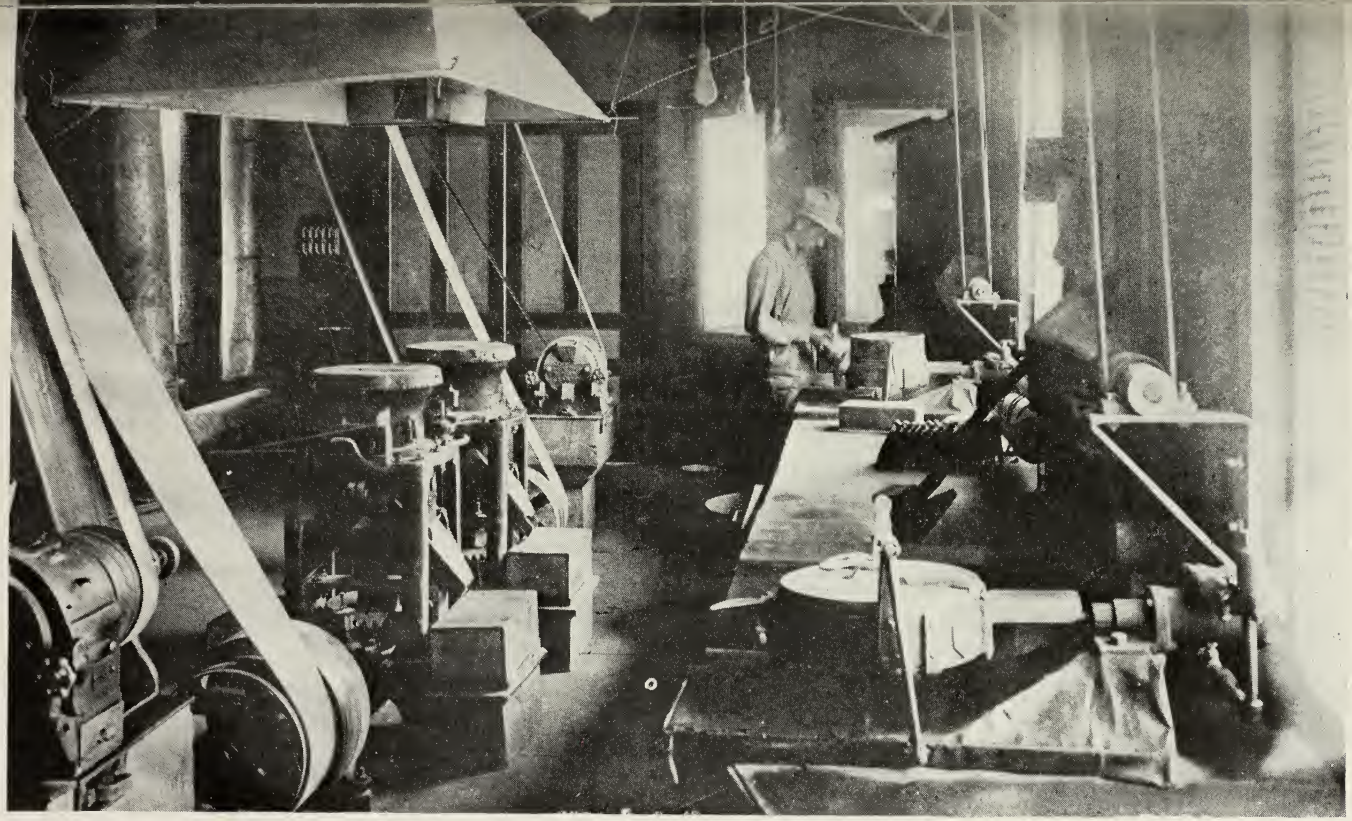


FIG. 30.—BUCKING ROOM AT ANACONDA SAMPLING MILL.

The duplicate and orderly arrangement of the equipment is prominent. The air-driven shaking sieves are on the bench at the right, the cube mixers are on the wall over the bench.

—Photograph by Baker, A. C. M. Co.

Flow Sheet of the Anaconda Sampling Mill—

Cars dump into bins under "high line"
Collecting car under bins supplies two 50-ton mill hoppers
Shaking trays
Jaw crushers; 12"x24"
Conveyors to elevators
Elevated to top of 4th floor
No 1 cutter; Brunton oscillatory, 11"x15" openings, 24 cuts per minute

Sample; 20%
Jaw crushers; 8"x18"
No 2 cutters; Brunton oscillatory, 7"x11" openings, 36 cuts per minute

Sample; 20%
Shaking trays
No. 1 rolls; 15"x40"
No. 3 cutter; Brunton oscillatory, 5.5"x8" openings, 44 cuts per minute

Sample; 20%
Distributing boxes
No. 2 rolls; 14"x26"
No. 4 cutters; Brunton oscillatory, 3.5"x5" openings, 76 cuts per minute

Sample; 20%
Trolley bucket or wheelbarrow to steel floor
Brunton split shovels
Sample

Steam cabinet dryers
Engelbach grinders
Stand cutters; 26-slot
Sample

Disk grinders
Mechanical sieves (air)
Cube mixers
Table riffles; 16-slot
Sealed packets

SAMPLING IN MONTANA CONCENTRATING AND CYANIDING MILLS

A great deal of sampling is done as part of the daily routine in all concentrating and cyaniding mills. In ore treatment plants conditions are decidedly favorable for cheap and accurate work. The greatest difficulty is unquestionably in the sampling of mill heads where hardly less than a full observance of all the rules for crushing and dividing can be expected to supply precise data.

Every tenth car of ore for the great Anaconda 17,000-ton concentrator is sampled in the Anaconda sampling mill which has already been described. All the ore going to the East Butte concentrator is sampled in the East Butte sampling mill, also one of the mills described in this paper. The Butte and Superior concentrator feed is hand sampled every half hour; 50 pounds are taken at each interval. The Timber Butte concentrator is equipped with a hand operated device which cuts out samples from the crushed feed as the stock pours from one conveyor head to another conveyor. The Shannon mine of the Barnes King Company is equipped with mechanical contrivances which automatically cut out portions of the ore at the tramway loading station; the sample is worked down to final pulp in the customary way.

The sampling of the different streams of mill pulp is carried out in different degrees by various means in the several mills. Usually hand samples are taken at designated intervals. Swinging stream samplers are built in a variety of models and frequently used. A complete automatic stream sampling system is in use at the Butte and Superior mill; an electrical timing and operating installation swings samplers across a half-dozen streams at exactly 8-minute intervals. Milling work inevitably smooths out inequalities in the raw ore; the material is abundantly crushed; mixings and dispersions occur throughout the line of pulp flow. The required precision of the sampling operation is obtained with slight expense for installation, upkeep, or attendance.

Mill products can be sampled as pulps while the concentrates are flowing to collecting bins; they can be pipe-sampled as lots in bins or in railroad cars, or they can be hand-sampled by shovel and cone and quarter methods.

As a rule, ordinary mill sampling, except for the sampling of the heads, is far easier to accomplish than the sampling of lots of custom ore; mill heads require practically the same treatment that lots get in the best of custom samplers.

SUMMARY AND CONCLUSIONS

The principles involved in ore sampling have been more or less expressed by several writers, but no thoroughly adequate and mathematical treatment has yet been given. The present paper attempts to analyze sampling methods with the theory of probability and the distribution of results strongly in mind, although a mathematical treatment is not attempted. A lot of ore is a very complex aggregate, and to the sampling deviations are added those of chemical analysis; constants in an equation of errors, or for qualifying Woodbridge's table of size-weight relationship.

The equipment for ore sampling which is described in these pages is only that equipment found in actual use in Montana at the present time; the range of the types is wide but by no means includes excellent machines in use elsewhere.

The figures given in connection with the descriptions of riffle mixing and pipe sampling may give a better insight into the character of those two operations.

Sampling is now carried on extensively in Montana in seven sampling mills and in at least five large and important ore-dressing mills. It has been attempted to outline the procedure used in the different sampling mills, but a full account of the sampling in the twelve places would require a much larger bulletin than this can presume to be.

Although sampling of ores and mill pulps is a perfectly practical and common operation, certain features are clearly open to change and improvement. The more obvious possibilities group about precision, cost, efficiency, fire risk, safety, welfare, and hygiene. There always lurks the suspicion that, for the work done, and the end attained, present plants are extravagant in elevations, size of buildings, and general capital outlay for equipment and attendance. Montana sampling mills rank high in most of their technical features, with certain attentions toward improvement in conditions of safety, welfare, and hygiene they would probably become the most advanced types in their field of technology.

The excellent results obtained by the State Bureau on the different samplings of the 50-ton lot of ore demonstrate the precision of the mills and the satisfaction and usefulness of mechanical sampling.

IMPORTANT PUBLICATIONS ON SAMPLING

1884—Brunton, D. W. "A New System of Ore-Sampling." Trans. Am. Inst. Min. Engrs., Vol 13, p. 639.
Brunton's first vibratory cutter is described.

1895—Brunton, D. W. "The Theory and Practice of Ore-Sampling." Trans. Am. Inst. Min. Engrs., Vol. 25, p. 826.
An extended study of the influence of large particles and rich minerals on the precision of sampling. Demonstrates the necessity for crushing between successive divisions.

1898—Hofman, H. O. "The Metallurgy of Lead." Hill Publishing Co., New York, 5th Ed., 9th Imp.
Chapter 5 is a lengthy discussion of hand and mechanical ore sampling.

1902—Johnson, Paul. "An Automatic System of Sampling." Eng. & Min. J., Vol. 73, p. 514.
Describes mill at Greenwood, B. C., with cuts and results.

1908—Argall, Philip. "Machine Sampling." Eng. & Min. J., Vol. 86, p. 291.
Refutes statement that retardation causes error in sampling.

1908—Woodbridge, T. R. "Sampling by Machine." Eng. & Min. J., Vol. 86, p. 917.
Discusses mechanical sampling with data.

1909—Bailey, E. G. "Accuracy in Sampling Coal." J. Ind. Eng. Chem., Vol. I., p. 161.
Discusses probability curves involving large errors.

1909—Richards, Robert H. "Ore Dressing." McGraw-Hill Book Co., New York. Vol. III., pps. 1570-1578.
Principles and practice of sampling are discussed.

1909—Brunton, D. W. "Modern Practice of Ore-Sampling." Trans. Am. Inst. Min. Engrs., Vol. 40, p. 567.
The Taylor and Brunton system is explained. Brunton's oscillatory cutter is described.

1909—Woodbridge, T. R. "Sampling by Machine." Eng. & Min. J., Vol. 87, p. 269.
Discusses mechanical sampling with data.

1910—Weld, Fred C. "Accuracy in Sampling." J. Ind. Eng. Chem., Vol. 2, p. 426.
Discusses application of probability curves to sampling.

1910—Huntoon, Louis D. "Accuracy of Mechanical and Riffle Ore Samplers." Eng. & Min. J., Vol. 90, p. 62.
Gives screen analyses and assays after riffle dividing.

1916—Woodbridge, T. R. "Ore Sampling Conditions in the West." U. S. Bureau of Mines, Technical Paper 86.

An excellent study of the more important aspects of hand and mechanical sampling. A general summary of western practice is given as well as flow sheets of the mills.

1919—Rice, Claude T. "Sampling Practice at Independence Mill." Eng. & Min. J., Vol. 107, p. 641.

Describes the Coard mixer and divider for final pulps.

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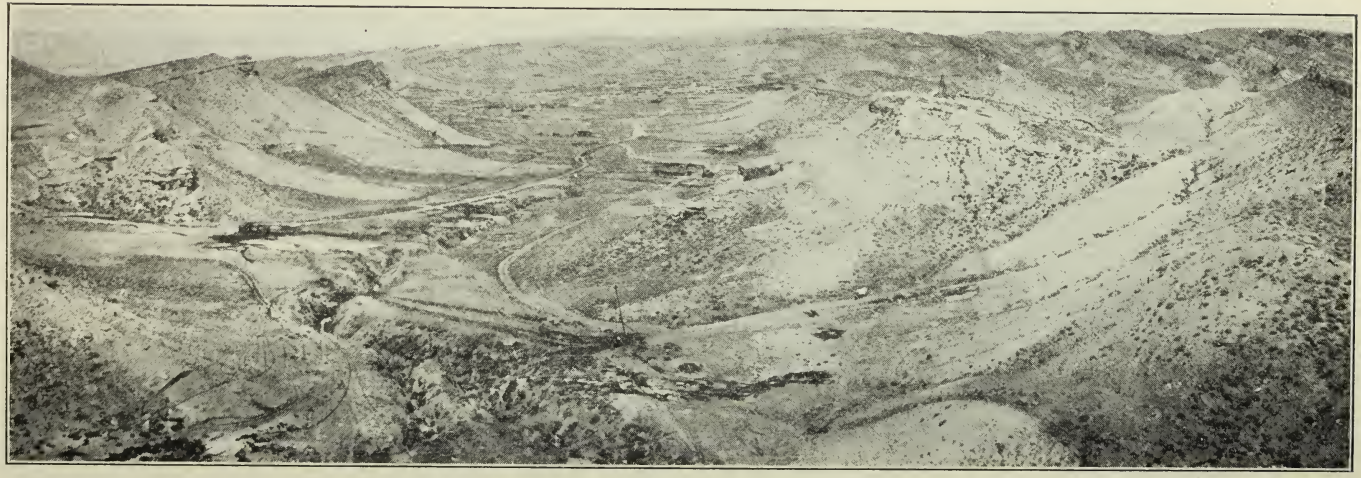

PLATE III.—ELK BASIN.

View from the south rim looking northward into Montana. The conspicuous escarpment has been produced by erosion along the crest of the anticline.

UNIVERSITY OF MONTANA BULLETIN

BUREAU OF MINES AND METALLURGY SERIES NO. 4

GEOLOGY AND OIL AND GAS PROSPECTS OF CENTRAL AND EASTERN MONTANA

BY

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B. S. School of Mines and Engineering, Univ. of Utah, 1919
BEVAN, ARTHUR C. - - - - - - - - Assistant Geologist
B. S. Ohio Wesleyan University, 1912.

PUBLICATIONS

No. 1. The Montana State Bureau of Mines and Metallurgy (an explanation of its purpose and operation).
No. 2. Directory of Montana Metal and Coal Mines.
No. 3. Mechanical Ore Sampling in Montana (by H. B. Pulsifer).
No. 4. Geology and Oil and Gas Prospects of Central and Eastern Montana (with a geologic map). (By C. H. Clapp, Arthur Bevan and G. S. Lambert.)

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PART I

BY

C. H. CLAPP

INTRODUCTION

Region and Field Work.

On account of the discovery of oil in central Montana, and the consequent interest in the oil resources of the state, the State Bureau of Mines and Metallurgy undertook a geological survey of the oil and gas possibilities of Montana. Because of the greatly deformed and fractured character of the rocks in the western, mountainous region, it was believed that only in the central and eastern portions of the state are oil and gas possibilities of immediate prospective value. Hence, during the first season, only that porton of the state east of the main front range of mountains was surveyed. However, as that portion constitutes nearly two-hirds of the entire state, 98,000 square miles out of a total of 147,000 square miles, a task of considerable magnitude for a single season was undertaken.

A base map on a scale of four miles to an inch was compiled and on this was assembled all of the available geological information from reliable sources, chiefly the publications of the United States Geological Survey. In this way, several areas, approximating 50,000 square miles in extent, were mapped with varying degrees of accuracy, leaving several large unmapped areas. Thus there remained to be mapped during the season of 1920 about 48,000 square miles of territory, distributed throughout central and eastern Montana.

Two parties were organized, one consisting of G. S. Lambert and Arthur Bevan, and the other of C. H. Clapp and R. J. Wade. Mr. Bevan left for the field on June 14, accompanied by C. W. Vaupell, who assisted him until July 1, when G. S. Lambert joined the party. Lambert and Bevan finished their field work on September 22. C. H. Clapp left for the field on July 9 and returned on August 28. Since then a 3-day trip was made to the Cat Creek oil field by Clapp and Lambert during the last part of December. There were only 152 party days spent on actual field work, which necessitated an average of 315 square miles of mapping per party day.

The mapping, therefore, was obviously of a reconnaissance nature, but was checked by the work of several private surveys, as well as by the work of the United States Geological Survey in areas not yet

published by them. No detailed work was, of course, possible. Nearly all the surveyed roads in the region were traversed in automobiles, locations being made from section corners and by measurement of distances with a speedometer. In unsurveyed townships, compass traverses were made of the roads, and distant contacts were located by a rough compass triangulation.

For publication the accompanying geologic map of central and eastern Montana, on a scale of 1:500,000, or about 8 miles to an inch, has been compiled by G. S. Lambert. The base map was compiled by the United States Geological Survey in 1913 and has been corrected and brought up to date by A. L. Longley with data from the United States Land Survey plats of 1913 to 1919.

Authorship and Acknowledgments.

The table of contents names the individual author of each portion of the report, but all portions were written after conference and discussion of all portions by all three authors. Much of the report must be considered as a compilation of reports already published, dealing with the geology and mineral resources of central and eastern Montana. Even for those areas, a geologic map of which has not been heretofore published, a large part of the information has been obtained from others.

It is not feasible, even if it were possible, to acknowledge by name all of those to whom credit is due for both general and specific information. The United States Geological Survey has furnished by far the major part of the data for both the report and map. Those papers prepared by the staff of the survey, which were actually used during the survey and preparation of the report are listed in the bibliography and specific mention is made to several of them throughout the report. In addition, a map of the central and eastern part of Montana was prepared by the United States Geological Survey showing several important geologic boundaries, especially in areas where no geologic maps have been published. These boundaries were not everywhere accepted, but were used where the writer's own work was too general or incomplete.

Acknowledgment to the Geological Department of the Anaconda Copper Mining Company should also be made. It was in this department that both the field and final maps were compiled and draughted. Although all members of the department contributed to the accuracy and value of the maps, specific acknowledgment is made to Mr. A. L. Longley in charge of the draughting, to Mr. P. R. Murphy, who compiled the geology for the field maps, and to Messrs. George Fowler and Paul Billingsly, who have been in charge of much of the areal geologic surveys and development for oil and gas carried on by the company.

Mr. Eugene Milburn of Miles City furnished the writer with many reports by various geologists obtained during his investigation of the

oil and gas resources of the state. Areal information has also been obtained from Mr. Julius H. Warner, of the East Butte Copper Company. Detailed information and logs of wells have been freely given by most of the oil operators and geologists of the state. To many others the authors are indebted for the aid which has been given to them.

Bibliography.

The following list is not a complete bibliography of all the papers relative to the geology and mineral resources of central and eastern Montana. A complete bibliography dealing with the geology of the state is being compiled and will be published later. In the following list an attempt has been made to give only the more important and latest papers, for where a later publication supersedes an earlier one, the earlier one has not been given. All papers used during the work have, of course, been listed. The papers are first listed in the order of their publication and then indexed according to the counties to which they refer.

(1) Hayden, F. V.,
Geology of the Missouri Valley: U. S. Geol. Survey. Terr. Prelim. (Fourth Ann.) Rept., 1871.

(2) Weed, W. H.,
The Laramie and the overlying Livingston formation of Montana: U. S. Geol. Survey Bull. 105, 1893.

(3) Iddings, J. P. and Weed, W. H.,
U. S. Geol. Survey Geol. Atlas, Livingston folio (No. 1), 1894.

(4) Weed, W. H. and Pirsson, L. V.,
Geology and mineral resources of the Judith Mountains of Montana; U. S. Geol. Survey, Eighteenth Ann. Rept., Part 3, pp. 437-616, 1898.

(5) Weed, W. H.,
Geology of the Little Belt Mountains, Montana; U. S. Geol. Survey Twentieth Ann. Rept. Part 3, 1899.

(6) Weed, W. H.,
U. S. Geol. Survey Geol. Atlas, Fort Benton folio (No. 5), 1899.

(7) Weed, W. H.,
U. S. Geol. Survey Geol. Atlas, Little Belt Mountains folio (No. 5), 1899.

(8) Willis, Bailey,
Oil of the northern Rocky Mountains: Eng. and Mining Jour., Vol. 72, pp. 782-784, 1901.

(9) Hatcher, J. B.,
Relative age of the Lance Creek beds of Converse County, Wyo., the Judith River beds of Montana, and the Belly River beds of Canada: Am. Geologist, Vol. 31, p. 369, 1903.

(10) Stanton, T. W., and Hatcher, J. B.,
The stratigraphic position of the Judith River beds and their correlation with the Belly River beds: Science, new ser., vol. 18, p. 212, 1903.

(11) Stanton, T. W., and Hatcher, J. B.,
Geology and palentology of the Judith River beds; U. S. Geol. Survey Bull. 257, 1905.

(12) Darton, N. H.,
Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, 1906.

(13) Darton, N. H.,
Coals of Carbon County, Montana: U. S. Geol. Survey Bull. 316-C, pp. 174-193, 1907.

(14) Fisher, C. A.,
Southern extension of the Kootenai and Montana coal bearing formations in northern Montana: Econ. Geol., vol. 3, pp. 94-96, 1908.

(15) Washburne, C. H.,
Coal fields of the northeast side of the Bighorn Basin, Wyo., and of Bridger, Montana: U. S. Geol. Survey Bull. 341, 1909.

(16) Fisher, C. A.,
Geology and water resources of the Great Falls region, Montana: U. S. Geol. Survey Water-Supply Paper 221, 1909.

(17) Leonard, A. G., and Smith, C. D.,
The Sentinel Butte lignite field, North Dakota and Montana: U. S. Geol. Survey Bull. 341-A, pp. 15-35, 1909.

(18) Collier, A. J., and Smith, C. D.,
The Miles City coal field, Montana: U. S. Geol. Survey Bull. 341-A, pp. 36-61, 1909.

(19) Stone, R. W.,
Coal near the Crazy Mountains, Montana: U. S. Geol. Survey Bull. 341-A, pp. 78-91, 1909.

(20) Woodruff, E. G.,
The Red Lodge coal field, Montana: U. S. Geol. Survey Bull. 341-A, pp. 92-107, 1909.

(21) Fisher, C. A.,
Geology of the Great Falls coal field, Montana: U. S. Geol. Survey Bull. 356, 1909.

(22) Calvert, W. R.,
Geology of the Lewistown coal field, Montana: U. S. Geol. Survey Bull. 390, 1909.

(23) Smith, C. D.,
The Fort Peck Indian Reservation lignite field, Montana: U. S. Geol. Survey Bull. 300, 1909.

(24) Pepperberg, L. J.,
The Milk River coal field, Montana: U. S. Geol. Survey Bull. 381-A, 1910.

(25) Stone, R. W., and Calvert, W. R.,
Stratigraphic relations of the Livingston formation of Montana: Econ. Geol. Vol. 5, pp. 551-557, 652-669, 741-761, 1910.

(26) Peale, A. C.,
On the stratigraphic position and age of the Judith River formation: Jour. Geol. 20, pp. 350-549, 640-652, 738-757, 551-7, 652-669, 741-764, 1912.

(27) Calvert, W. R.,
Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471-D, pp. 187-201, 1912.

(28) Bowen, C. F.,
The Baker lignite field, Montana: U. S. Geol. Survey Bull. 471-D, pp. 202-226, 1912.

(29) Herald, F. A.,
The Terry lignite field, Montana: U. S. Geol. Survey Bull. 471-D, pp. 227-270, 1912.

(30) Hance, J. H.,
The Glendive lignite field, Montana: U. S. Geol. Survey Bull. 471-D, pp. 271-283, 1912.

(31) Stebinger, Eugene,
The Sidney lignite field, Montana: U. S. Geol. Survey Bull. 471-D, pp. 284-318, 1912.

(32) Beekly, A. L.,
The Culbertson lignite field, Montana: U. S. Geol. Survey Bull. 471-D, pp. 319-358, 1912.

(33) Pepperberg, L. J.,
The southern extension of the Milk River coal field, Montana: U. S. Geol. Survey Bull. 471-E, pp. 359-383, 1912.

(34) Calvert, W. R.,
The Livingston and Trail Creek coal fields, Montana: U. S. Geol. Survey Bull. 471-E, pp. 384-405, 1912.

(35) Calvert, W. R.,
The Electric coal field, Montana: U. S. Geol. Survey Bull. 471-E, pp. 406-422, 1912.

(36) Rogers, G. S.,
The Little Sheep Mountain coal field, Montana: U. S. Geol. Survey Bull. 531-F, pp. 159-227, 1913.

(37) Bauer, C. M.,
Lignite in the vicinity of Plentywood and Scobey, Montana: U. S. Geol. Survey Bull. 541-H, pp. 293-315, 1914.

(38) Rogers, G. S.,
Geology and coal resources of the area southwest of Custer, Yellowstone and Big Horn counties, Montana: U. S. Geol. Survey Bull. 541-H, pp. 316-328, 1914.

(39) Bowen, C. F.,
Coal discovered in a reconnaissance survey between Musselshell and Judith, Montana: U. S. Geol. Survey Bull. 541-H, pp. 329-337, 1914.

(40) Bowen, C. F.,
The Cleveland coal field, Montana: U. S. Geol. Survey Bull. 541-H, pp. 338-355, 1914.

(41) Bowen, C. F.,
The Big Sandy coal field, Montana: U. S. Geol. Survey Bull. 541-H, pp. 356-378, 1914.

(42) Huntley, L. G.,
Oil, gas, and water content of Dakota sand in Canada and the United States: Am. Inst. Min. Eng. Bull. 102, pp. 1333-1353, 1915.

(43) Rowe, Jesse Perry,
Probable oil and gas in Montana: Eng. and Min. Jour., vol. 99, pp. 647-649, 1915.

(44) Bowen, C. F.,
Possibilities of oil in the Porcupine dome, Montana: U. S. Geol. Survey Bull. 621-F, pp. 61-70, 1916.

(45) Stebinger, Eugene,
Geology and coal resources of northern Teton County, Montana: U. S. Geol. Survey Bull. 621-K, pp. 117-156, 1916.

(46) Rowe, J. P. and Wilson, R. A.,
Geology and economic deposits of a portion of eastern Montana: Univ. of Montana (State University) Studies, No. 1, 1916.

(47) Bard, D. C., and Steele, Chester,
Present status of oil and gas prospecting in Montana: Quarterly Journal of the Montana Soc. of Engineers, vol. 1, No. 3, pp. 329, 1916.

(48) Stebinger, Eugene,
Possibilities of oil and gas in north central Montana: U. S. Geol. Survey Bull. 641-C, pp. 49-91, 1917.

(49) Calvert, W. R.,
Geology of the Upper Stillwater Basin, Montana: U. S. Geol. Survey Bull. 641-G, 1917.

(50) Barnett, V. H.,
Geology of the Hound Creek district of the Great Falls coal field, Montana: U. S. Geol. Survey Bull. 641-H, pp. 215-231, 1917.

(51) Stebinger, Eugene,
Anticlines in the Blackfeet Indian Reservation, Montana: U. S. Geol. Survey Bull. 641-J, pp. 281-305, 1917.

(52) Richards, R. W., Lupton, C. T., and Woolsey, L. H.,
The Bull Mountain coal field, Montana: U. S. Geol. Survey Bull. 647, 1917.

(53) Collier, A. J.,
The Bowdoin dome, Montana; a possible reservoir of oil or gas; U. S. Geol. Survey Bull. 661-E, pp. 193-209, 1917.

(54) Hancock, E. T.,
Geology and oil and gas prospects of the Lake Basin Field, Montana: U. S. Geol. Survey Bull. 691-D, pp. 101-148, 1918.

(56) Stebinger, Eugene,
Oil and gas geology of the Birch Creek-Sun River area, northwestern Montana: U. S. Geol. Survey Bull. 691-E, pp. 149-184, 1918.

(56) Bowen, C. F.,
Anticlines in a part of the Musselshell Valley, Montana: U. S. Geol. Survey Bull. 691-F, pp. 185-210, 1919.

(57) Hancock, E. T.,
Geology and oil and gas prospects of the Huntley field, Montana: U. S. Geol. Survey Bull. 711-G, 1920.

(58) Thom, W. T.,
An Upper Cretaceous seacoast in Montana: John Hopkins Univ. Circ. new ser., No. 3, pp. 68-73, March, 1917.

(59) Collier, A. J.,
Geology of northeastern Montana: U. S. Geol. Survey Prof. Paper 120-B, pp. 17-39, 1918.

(60) Condit, D. D.,
Relations of late Paleozoic and early Mesozoic formations of southwestern Montana and adjacent parts of Wyoming: U. S. Geol. Survey Prof. Paper 120, pp. 111-121, 1918.

(61) Bowen, C. F.,
Gradation from continental to marine conditions of deposition in central Montana during the Eagle and Judith River epochs; U. S. Geol. Survey Prof. Paper 125-B, pp. 11-21, 1919.

(62) Cross, Whitman,
Are the Lance and Fort Union formations of Mesozoic time? Science, p. 305, April 1, 1921.

(63) Schuchert, Charles,
Are the Lance and Fort Union formations of Mesozoic time? Science, pp. 45-47, Jan. 14, 1921.

(64) Knowlton, F. H.,
Are the Lance and Fort Union formations of Mesozoic time? Science, p. 307, April 1, 1921.

County—	(Numbers refer to the foregoing bibliographic list)
Big Horn	(12) (38) (57) (60)
Blaine	(24) (33) (40) (48) (59)
Carbon	(13) (15) (20) (49) (60)
Carter	
Cascade	(5) (6) (7) (16) (21) (48) (50)
Chouteau	(6) (41) (48)
Custer	(18) (27) (28) (29) (36)
Dawson	(27) (30) (31)
Fallon	(27) (28) (29)
Fergus	(4) (6) (7) (16) (21) (22) (39) (48) (61)
Flathead	(8)
Gallatin	(3) (7) (34) (60)
Garfield	(59) (61)
Glacier	(45) (48) (51)
Hill	(24) (33) (48)
Lewis & Clark	(55)
Liberty	(45) (48)
McCone	(23) (59)
Madison	(60)
Meagher	(5) (7) (19) (56)
Musselshell	(39) (52) (54) (56)
Park	(3) (7) (34) (35) (60)
Phillips	(48) (53) (59)
Pondera	(45) (48) (51) (55)
Powder River	
Prairie	(27) (29) (36)
Richland	(23) (27) (31) (59)
Roosevelt	(23) (32) (59)
Rosebud	(36) (44) (61)
Sheridan	(32) (37) (59)
Stillwater	(3) (49) (54) (60)
Sweetgrass	(3) (7) (34) (54) (56) (60)
Teton	(48) (55)
Toole	(45) (48) (51)
Valley	(23) (53) (59)
Wheatland	(7) (19) (52)
Wibaux	(17) (27) (29) (30) (31)
Yellowstone	(38) (54) (57) (60)
General Stratigraphy	(1) (2) (9) (10) (11) (14) (25) (26) (58) (62) (63) (64)
Other General Papers	(42) (43) (46) (47)

SURFACE FEATURES.

The eastern part of Montana is in the Great Plains region of North America, and the western part lies within the Rocky Mountain system of the mountainous Cordellera of the continent. Thus the state is divided into a western mountainous district and an eastern plains or prairie district, constituting almost two-thirds of the state. Although the boundary between the two districts is fairly well defined, crossing the state with a general N. 35° W. trend, the western part of the prairie district is characterized by several small ranges or groups of mountains, rising island-like above the general prairie level for over 200 miles east of the main mountain front. The prairie region itself may, therefore, be subdivided into a western and an eastern part, Central Montana and Eastern Montana. Thus the surface features of Montana divide the state into three distinct geographic districts, Western, Central and Eastern Montana. This report deals exclusively with Central and Eastern Montana.

In Central Montana the rocks are conspicuously folded with a general northwest trend, whereas in Eastern Montana, except in two or three places, the rocks are nearly flat lying or dip at angles of less than five degrees. Hence in Central Montana the more resistant rocks form the ranges and groups of mountains, which rise island-like above the general level of the prairies by 2000 to 6000 feet, whereas in Eastern Montana there are no distinct groups of mountains, although in places high cuestas, mesas, and buttes surmount the general prairie level by 1000 to 2000 feet.

Central and Eastern Montana are drained by prevailingly eastward and northeastward flowing, consequent streams, and owing to the semi-arid climate by only relatively few tributaries of an insequent nature. In Central Montana, however, some of the tributary streams follow soft rock belts and hence are subsequent streams. With the exception of St. Mary River, which rises in the mountains a few miles south of the Canadian border and enters the Saskatchewan, all the rivers drain into the Missouri, which, rising in the mountains, flows generally eastward across the prairie. Its main tributary, the Yellowstone, rises in the mountains of northwestern Wyoming and flows northeast, joining the Missouri in North Dakota just east of the Montana line. These two rivers divide Central and Eastern Montana into three nearly equal portions extending east from the mountains to the North Dakota boundary.

North of the Missouri, following for some distance the pre-Glacial channel of the Missouri, is the Milk River. Between the Missouri and the Yellowstone is the Musselshell. South of the Yellowstone are several large streams, flowing into it, which, enumerated from west to east, are the Big Horn, Rosebud, Tongue, and Powder rivers, all except the Rosebud having their source in Wyoming. The extreme

southeastern part of the state is crossed by Little Missouri River, which enters the Missouri in North Dakota.

The outlying ranges and groups of mountains of Central Montana consist from north to south of the Sweetgrass Hills, near the Canadian border; the Bearpaw and Little Rocky mountains, between the Milk and Missouri rivers; the Little Belt, Highwood, Moccasin, and Judith mountains south of the Missouri; the Castle and Big Snowy mountains, north of the Musselshell; the Crazy mountains between the Musselshell and Yellowstone rivers; and the Pryor and Bighorn mountains south of the Yellowstone. The Pryor mountains, lying wholly within Montana, are the northwestern portion of the Bighorn Mountains uplift, which was completely bisected by the Bighorn River.

Most of the mountains enumerated above are relatively low, in groups which are 10 to 40 miles across, each of which consists of a maturely eroded dome, exposing in most groups a central core of resistant igneous rocks. Only the higher peaks of the Little Belts, Big Snowy, Crazy, and Bighorn mountains have been glaciated into saw-tooth or serrated summits, whereas the other peaks, although usually steep and rugged, have more or less rounded or nearly level summits. The highest summits occur in the Crazy Mountains, which, although carved from nearly flat sediments intruded by resistant igneous rocks, are over 11,000 feet above sea level, or 6000 feet above the surrounding plains.

Eastern Montana consists of a broad, nearly level or gently sloping plain, above which remnants of former plains and slopes still remain to form mesas, buttes, and cuestas. Cut into the plain are the youthful to mature valleys of the present streams, which, in some places, have developed broad flood plains, and, in other places, still flow in narrow, although not very deep, gorges. In most places the insequent tributary streams of the larger rivers, throughout a zone varying in width from less than a mile to over 10 miles, have cut the prairie plain into breaks or bad lands.

The prairie plains slope in general toward the north and northeast, so that the elevation of the dominant rolling prairie plain ranges from 4000 feet above sea-level in Central Montana to 2300 feet in the extreme northeastern part of the state. Into this plain the larger rivers have cut their valleys to a depth of 100 to 500 feet. The lowest elevation in the state occurs where the Missouri and the Yellowstone cross the North Dakota boundary, each at an elevation of somewhat less than 1900 feet above sea-level.

Few of the buttes, mesas, or cuestas surmount the prairie level by more than 500 to 1000 feet. The principal mesas are the gravel covered plateaus along the Canadian border(1); Larb Hills between the

(1) Described by A. J. Collier, Geology of northeastern Montana; U. S. Geol. Survey, Prof., Paper 120-B, page 19, 1918.

Milk and Missouri rivers; the Piney and Black buttes north of the Missouri; the Sheep and Little Sheep mountains north of the Yellowstone; Bull Mountains between the Musselshell and Yellowstone rivers; Pine Ridge between the Yellowstone and Bighorn rivers; and a number of conspicuous white buttes in the southeastern part of the state.

The Wolf and Rosebud mountains are the highest and most extensive of the mesas. Taken as a whole they form a broad synclinal plateau between Little Bighorn River and the deeply eroded northern part of the Black Hills uplift in the southeastern corner of the state. The western portion of the plateau, to which the name of Wolf Mountains is applied, forms a westward facing cuesta, whose steep front slope is from 1500 to 2000 feet high, the maximum elevation of the cuesta being 5663 feet above sea-level. The rocks, and hence the surface of the cuesta, dip gently eastward to elevations of less than 4000 feet. The eastern portion of the plateau, known as Piniele Ridge, forms a far less conspicuous eastward facing cuesta surmounting the lowland plain cut in the non-resistant rocks of the Black Hills uplift. The plateau is deeply cut by the Rosebud, Tongue, and Powder rivers, and near its northern edge is dissected into a number of small mesas and buttes surmountaing the prevailing lowland level, which merges toward the north and east into the rolling prairie characteristic of the greater part of Eastern Montana.

North of the Yellowstone in the vicinity of Forsyth, is a dome shaped uplift 40 by 30 miles, the limbs of which dip at angles up to 40 degrees. Where the more resistant rocks dip more steeply than 10 degrees, conspicuous ridges are formed. Similar ridges occur along the steeply dipping southwestern limb of the Cedar Creek anticline, extending from Glendive on the Yellowstone S. 30° E. into North Dakota. Less conspicuous and smaller ridges or cuestas surround the Black Hills uplift in the extreme southeastern portion of the state.

In a few placees, in and near the dome northwest of Forsyth and west of Jordan between the Piney and Black buttes, are resistant dikes of igneous rocks which form small ranges. Smoky Buttes, west of Jordan, is the most conspicuous, surmounting the prairie level by 400 feet.

GENERAL GEOLOGY.

The sedimentary rocks of Eastern Montana are almost everywhere flat lying or gently dipping. The older sedimentary rocks of Central Montana have, however, been deformed and intruded by igneous rocks, while the sedimentary rocks of Western Montana are still older and more deformed and have been intruded by larger and more frequent bodies of igneous rocks. The base of the main front range of the Rocky Mountain system roughly marks the boundary between the less deformed rocks of Eastern and Central Montana and the greatly deformed and igneous rocks of the western part of the state, and has

been taken as the western boundary of the area mapped and described in this report.

Although the sedimentary and metamorphic rocks of Montana range in age from the most ancient, Archean, to the most modern, Quaternary and Recent, those of Central Montana are dominantly of middle age, late Paleozoic and Mesozoic, and those of Eastern Montana are dominantly early modern, late Mesozoic and presumably early Cenozoic. A large part of Central and Eastern Montana is covered by a mantle of loosely consolidated or unconsolidated drift, which north of the Missouri river consists chiefly of glacial detritus. Elsewhere the drift consists of gravels, sands, and muds deposited in the streams and lakes which have drained the mountains to the west, from the time of the mountainous uplift in the early Cenozoic. Of these mantle rocks, however, only the Recent alluvium deposits in the valleys of the larger rivers have been mapped.

The oldest rocks shown on the accompanying map, the Madison limestone, and rocks of the Quadrant formation, are of late Paleozoic, Mississippian and Pennsylvanian, ages. They are exposed only around the flanks of the mountain uplifts of Central Montana. Overlying them, and structurally speaking, virtually conformable with them, although angular unconformities do occur, are the rocks of Mesozoic and early Cenozoic(?) (Fort Union) ages, several thousand feet in thickness. In spite of their great thickness and the great length of time during which they were deposited, no significant angular unconformities, indicating widespread deformation and prolonged erosion occur. There are, however, certain horizontal unconformities or disconformities, indicating time intervals during which there was little or no deposition, but doubtless some local erosion.

However, resting upon the older rocks, with marked angular unconformity, and exposed only in the southeastern part of the state, are sedimentary rocks of early Cenozoic (Oligocene) age, known as the White River beds. Thus it appears as if the only marked period of deformation and igneous intrusion that has affected the Mesozoic and Fort Union rocks of Montana, occurred after the deposition of the Fort Union and previous to the deposition of the White River beds. The exact age of the Fort Union is doubtful. It has been generally considered to be of earliest Cenozoic, Eocene, age, and has been so considered in this report and on the accompanying map. But as discussed later it is perhaps better considered to be of latest Mesozoic, that is, latest Cretaceous age, in which case the period of deformation must have occurred during the Epi-Mesozoic (Mesozoic-Cenozoic) interval or during the Eocene epoch.

During the deformation the rocks of Central Montana were flexed into open folds with a general northwest trend, the actual bearing of the axes of the major folds varying from N. 15° W. to nearly due East and West. Although the limbs of some of the major folds were steeply tilted to angles of 25 to 50 degrees from the horizontal, in

most of the folds east of the main front range the limbs were not more steeply tilted than 5 to 10 degrees.

In Eastern Montana the rocks were only slightly tilted toward the northeast, or were gently uplifted to form large, isolated anticlines. With one exception, a relatively narrow anticline in the extreme eastern part of the state, the anticlines are dome shaped uplifts 10 to 50 miles across, from which the component rocks dip away in all directions. The crest of the dome in the southeastern corner of the state occurs in Wyoming, so that in Montana the rocks dip only to the northeast, north, and northwest.

The major axis of folding in Central Montana extends along the crest of the Bighorn Mountains uplift, through a region characterized by several small folds, to the Little Belt Mountains uplift; and thence north along the crest of a broad, northward plunging, uplift, called the Sweetgrass arch, to the Canadion border. The general trend of the axis is N. 33° W. but in detail it varies from N. 15° to 75° W.

The Bighorn Mountains uplift in Montana consists of a northwesterly plunging anticline 30 miles across, striking N. 50° W. Although in places the limbs of the anticline dip at angles of more than 45°, in most places they dip at angles of less than 20°. Furthermore, the rocks flatten out rapidly away from the uplift and the limbs of the major fold, except as described below, are fairly regular and free from faults, although there are several places where the limbs flatten out to form noses or terraces, and along the flanks there are a few closed anticlines and domes.

Along Yellowstone River, in the vicinity of Billings, 25 miles north of the Pryor Mountains, the younger rocks have been affected by the Bighorn Mountains uplift and have been deformed into a number of minor folds broken by numerous faults.(2) The most remarkable feature of the structure is a long narrow belt of faulting 82 miles long, but not more than 6 miles wide, extending from Township 4 North, Range 17 East, to Township 1 North, Range 31 East. The belt trends N. 80° W. but the faults almost universally strike to the northeast, N. 50° E. being the average strike. Hancock(3) suggests torsional movements as a probable cause of the localized faulting along the narrow belt, the torsional stresses resulting from the Big Horn uplift to the south and the group of small uplifts and Little Belt Mountain uplift to the northwest.

North of the belt of faulting and southeast of the Little Belt Mountains uplift there are, as has already been mentioned, several relatively small folds whose axes, like the faults just described, have a general easterly or northeasterly trend. Of these the major folds are the Big Coulee-Hailstone dome, the Shawmut anticline, and the Elk

(2) For detailed description of the structure see Hancock, E. T., Geology and Oil and Gas Prospects of the Huntley Field, Montana; U. S. Geol. Survey Bull. 711-G, pages 139-140, 1920; and Geology and Oil and Gas Prospects of the Lake Basin Field, Montana, U. S. Geol. Survey Bull. 691-D, pages 131-141, 1918.

(3) Idem.

uplift. The three major structures may themselves be divided into minor anticlines, domes, and terraces, forming on the east and northeast flanks of the Big Coulee-Hailstone dome, the Broadview dome and Belmont terrace, and on the southwest flank the Gibson dome; at the west end of the Shawmut anticline the West, Middle and East Domes; and in the Elk uplift, the Big Elk, Little Elk, Haymaker, and Daisy Dean domes.

The Little Belt Mountains uplift is a large anticline, 85 miles long, and 50 miles across, striking N. 75° W. It plunges in all directions except toward the west and southwest, in which directions it merges into the still larger anticline that forms the Big Belt Mountains, one of the front ranges of the Rocky Mountains. The limbs of the Little Belt Mountains anticline are flexed into several minor folds and are broken by faults. Most of the minor folds plunge away from the major uplift to form a series of radial crests. Some of them, however, are completely enclosed to form domes such as the Skull Butte and Stockett domes.

The Sweetgrass arch, north of the Little Belt Mountains uplift, is a broad, flat topped anticline, 130 miles long, and 80 miles wide. It strikes N. 15° W. and plunges to the northwest. The limbs of the folds dip at very low angles and are flexed into but few minor anticlines or terraces. There may be local anticlines and domes within the arch, but this can be determined only by detailed field work.

Between the major axis of anticlinal folding just described and the axis of much greater deformation along the main front range of the Rocky Mountain system, is a synclinal area 15 to 75 miles wide. It is, however, interrupted in its central portion by an anticline, which extends east from the Big Belt Mountains anticline through the Little Belt Mountains and Big Snowy Mountains anticlines into eastern Montana. Within the synclinal area are numerous, relatively small anticlines and domes. Those south of the Little Belt Mountains anticline are Potter Basin dome, McLeod dome, Dean anticline, Dry Creek dome, and, with only their northern parts within Montana, Elk Basin and Frannie domes. North of the Little Belt Mountains the synclinal area may be divided, as described by Stebinger(4), into two structural areas, an eastern area in which the beds are nearly horizontal or very gently folded, and a western area in which the beds have been greatly folded and broken by faulting. In the eastern area the rocks dip gently westward at an average angle of 20° to 30°, but there are several terraces and anticlines, of which the larger and better enclosed are the Willow Creek anticline, Dupuyer anticline, Scoffin Butte anticline, the anticlines on Birch Creek, the Blacktail Creek anticline, the Cut Bank Creek anticline and one 3 miles to the southwest,

(4) Stebinger, Eugene, Geology and coal resources of northern Teton County, Montana; U. S. Geol. Survey Bull. 621-K pp. 128-129, 1916; Anticlines in the Blackfeet Indian Reservation, Montana; U. S. Geol. Survey Bull. 641-J., pp. 292-294, 1917; and Oil and gas geology of the Birch Creek-Sun River Area, Northwestern Montana, U. S. Geol. Survey Bull. 691-E., pp. 168-182, 1919.

and an anticline on the North Fork of Milk River. In the western area the folds are all long and narrow and many are broken by strike faults, but there are several enclosed anticlines which are structurally favorable to the accumulation of oil and gas. These are noted and named on the accompanying geologic and structural maps.

The huge east-west anticline, which, as described above, interrupts the synclinal area east of the main front range, has a general N. 81° W. trend, although the western portion strikes more nearly east and west than the eastern portion. The anticline is characterized by several minor anticlines and domes, and hence is properly called an anticlinorium. East of the Little Belt Mountains anticline, which has already been described, there is a well defined anticline along the north and along the south edge of the anticlinorium, the two anticlines being separated by a broad, nearly flat, synclinal area. The outer limbs of the two anticlines dip steeply away from the major axis at angles ranging from 5° to 85°, averaging in the western portion 40° to 50° and in the eastern portion 5° to 10°, whereas the inner limbs dip gently toward the central synclinal area at angles averaging less than 5°.

Just east of the Little Belt Mountains the two anticlines consist of the Big Snowy Mountains uplift on the south and a number of much smaller uplifts forming the Judith and Moccasin mountains on the north. The latter are to a great extent laccolithic uplifts(5) and it is probable that the former is of the same nature, although, as yet, no extensive core of igneous rocks has been exposed by erosion in the Big Snowy Mountains. The asymetrical character of the southern anticline is well developed in the Big Snowy Mountains uplift, but not in the Judith and Moccasin Mountains uplifts. Furthermore, the central synclinal area between the two major uplifts is distinguished by several smaller domes which also appear to be laccolithic in origin(6).

Farther east the two anticlines are known as the Cat Creek anticline on the north and the Devil's Basin anticline on the south. The two anticlines pitch in general to the southeast away from the Judith and Big Snowy Mountains uplifts, but are characterized by several domes, forming completely enclosed structures. Along the Cat Creek anticline there are from west to east the Black Butte, Kootenai, Brush Creek, Oiltana, West Mosby, and East Mosby domes. Along the Devil's Basin anticline there are from west to east the Devil's Basin, Big Wall, Howard Coulee and Ragged Point domes.

Between the Cat Creek and Devil's Basin anticlines the synclinal area is warped into broad open folds, the largest of which consists of the Button Butte terrace and the Flat Willow anticline.

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(5) Weed, W. H., and Pirsson, L. V., Geology and mineral resources of the Judith Mountains of Montana; U. S. Geol. Survey, Eighteenth Ann. Rept. Part 3, pp. 437-616, 1898.

(6) Calvert, W. R., Geology of the Lewistown coal field, Montana; U. S. Geol. Survey Bull. 390, pp. 48-51, 1909.

East of Musselshell River the two anticlines are less well developed and both culminate and terminate in a single huge dome, 40 by 30 miles, called the Porcupine dome. The anticlines do continue, however, and the northern is represented by the McGinnis Creek dome in township 13 North, Range 34 East, and a terrace on the north flank of the Porcupine dome in townships 13 and 14 North, Ranges 37 and 38 East; and the southern is represented by the Sumatra anticline, Ingomar dome, and a terrace on the south flank of the Porcupine dome in Townships 6 and 7 North, Ranges 37 and 38 East. The only rocks younger than the definitely known Cretaceous (Colorado and Montana) in the entire anticlinorium form a synclinal area of Lance sandstones between the Sumatra anticline and the McGinnis Creek dome.

Between the Devil's Basin anticline and the Big Coulee-Hailstone dome and Shawmut anticline are two anticlines. The northeastern, which plunges to the southeast, is divided into two parts called the Devil's Pocket and Pole Creek anticlines, and the southern, which is completely enclosed with relatively steep dips on the northeast and southwest, is called the Woman's Pocket anticline.

North of the low east-west anticlinorium is another less well developed anticlinorium striking N. 60° W. Along its axis are three groups of dome shaped uplifts, presumably laccolithic in character. These form, from northwest to southeast, the Sweetgrass Hills and Bearpaw and Little Rocky mountains. All of them have a central core of igneous rocks, although those in the Bearpaw Mountains are largely of volcanic origin.

Between the Moccasin and Judith mountains on the south and the Bearpaw Mountains on the north and also to the north of the Bearpaw Mountains are several small anticlinal or monoclinal structures most of them faulted.(7) The better known of these are the structures in the vicinity of Winifred, south of the Bearpaw mountains, and the Havre, Brown's Coulee, Red Rock Coulee, Lodge Creek, Battle Creek, Coal Creek, and Signal Butte anticlines north of the Bearpaw Mountains.

With one exception the Cedar Creek anticline, the major uplifts of Eastern Montana are dome shaped. In the northern part of the state is the Bowdoin dome(8) over 60 miles in diameter but with very low dips, usually less than 1°. On the southeast flank of the Bowdoin dome, completely enclosed but virtually a terrace, is the Poplar dome, 20 miles in diameter. Between the two domes are at least two anclines. The one best developed extends through Wolf Point with a general N. 20° W. trend, with limbs which have a maximum dip of 4°. To the north of the Poplar dome are three low anticlinal areas

(7) Stebinger, Eugene, Oil and gas in north-central Montana U. S. Geol. Survey Bull, 641-C, pp. 65-88, 1917.
(8) Collier, A. J., The Bowdoin dome, Montana;. U. S. Geol. Survey Bull. 661-E, pp. 205-207, 1917.

forming the Coal Creek dome, Scobey anticline, and Big Muddy Creek dome.

In the central part of Eastern Montana is the Porcupine dome already described and the long relatively narrow anticline, known either as the Cedar Creek or Glendive-Baker anticline, which extends from north of the Yellowstone River, west of Glendive, S. 30° E. into North Dakota. The west limb of the anticline is much steeper than the east limb, having an average dip of about 20° whereas, the average dip of the east limb is less than 5°. West of Baker the west limb is complicated by minor folds, the axes of which are parallel to the major fold.

In the southeastern corner of the state are two dome shaped uplifts with a broad terrace to the west. The uplifts represent the northern extension of the major Black Hills uplift into Montana. Between the two uplifts is a shallow synclinal area which is complicated by both minor parallel and cross folds. The southern and larger of the two uplifts is also complicated by both parallel and cross minor folding to form in places enclosed anticlines such as the Seven Mile and Five Mile domes.

PART II

CRETACEOUS AND TERTIARY CONTINENTAL FORMATIONS

BY

C. H. CLAPP

The rocks which overlie the definitely known Cretaceous rock of the Montana group have been mapped as belonging either to the Lance or to the Fort Union formations. In general they have been formed under very different conditions from the underlying rocks which are largely marine and are continuous and fairly uniform over large areas. The rocks of the Lance and Fort Union formation are almost entirely of fresh water or continental origin, and vary greatly in detail within relatively limited areas; although their general characteristics are persistent through the greater part of Central and Eastern Montana. The age of these two formations has been the subject of a great deal of controversy, which lately has broken out with renewed vigor. It is out of place to discuss the subject in detail in a report of this kind, especially as the authors have not given the matter detailed study.

The United States Geological Survey after a consideration of all available evidence, (9) most of which has been secured by its own investigators, considers the Lance formation to be of doubtful lowermost Tertiary age and the Fort Union to be definitely of Tertiary, Eocene age. Some of the Survey geologists, (10)for several reasons, such as the recently discovered occurrence of a marine member, the Cannonball, in the upper part of the Lance in southwestern North Dakota, which carries a fauna much more closely connected with the Cretaceous than with the Eocene, believe that the Lance is Cretaceous. Schuchert(11) has gone further and considers both the Lance and Fort Union as Cretaceous, basing his conclusion largely on the essential continuity of the Fox Hills, Lance, and Fort Union. With this premise the present author is in complete agreement. Even Knowlton(12) one of the strongest advocates of the theory that the

(9) Cross, Whitman, Science, April 1, 1921, page 305.
(10) The latest paper is by Stanton, T. W., The Fauna of the Cannon-ball marine member o fthe Lance formation U. S. Geol. Survey Prof. paper 128-A, 1920.
(11) Schuchert, Charles, Are the Lance and Fort Union formations of Mesozoic Time? Science, pp. 45-47, Jan. 14, 1921.
(12) Knowlton, F. H., Science, April 1, 1921, page 307.

Lance and Fort Union formations are of Tertiary age, states that, "If the Cannonball marine member of the Lance formation is Cretaceous, then both Lance and Fort Union are Cretaceous, for there is no stopping short of the top of the Fort Union." If diastrophism is to be the basis of periods or systems, certainly Schuchert's conclusion is sound, for, from the extensive reconnaissance carried on in Montana, there is no question that there is no essential break, sudden change, or marked deformation following the close of the deposition of the Bearpaw shale until after the deposition of the Fort Union formation.

The late Cretaceous sandstanes of Fox Hills age, variously mapped in Montana as Lennep, Colgate, and Horsethief sandstones so closely resemble the overlying true Lance, it was impossible by rapid reconnaissance to distinguish between them on lithologic or structural grounds. There is no important or widespread erosion interval, and in many places there is no essential lithologic difference between the sandstones which, at the top of the Bearpaw, are found interbedded with it in a transitional zone 30 to 60 feet thick, and the normal sandstones of the unquestioned Lance. Therefore, for the purpose of the reconnaissance mapping all the sandstones and clays largely of fresh water origin directly overlying the Bearpaw Shale were mapped as Lance, and have been considered as of Cretaceous age. The lower limit of the Lance has been placed at the base of the first thick and persistent sandstone overlying the Bearpaw shale.

The upper limit of the Lance has been determined partly by the difference in color between the Lance and overlying Fort Union; the Lance in general being dull and somber, whereas, the Fort Union shows bright, contrasting colors. The limit has been determined largely, however, by the occurrence, either of the Lebo shale, the basal member of the Fort Union, or of the lowest persistent coal or lignite seam. In this report, following the practice of the United States Geological Survey, the Fort Union has been considered as of Tertiary, Eocene, age.

Fort Union formation.—The Fort Union formation was named in 1862 by Meek and Hayden(13) from a former military post on the Missouri River in North Dakota, about 3 miles from the Montana boundary, where the formation is typically exposed. For several years the rocks of the Fort Union and Lance formations were referred to the Laramie, but since 1907, when detailed work in the lignite and coal areas of Montana and North Dakota was begun by the United States Geological Survey, the rocks have been definitely subdivided into the Lance and Fort Union formations.

The Fort Union directly underlies the greater part of Eastern

(13) Meek, F. B., and Hayden, F. W., Description of new lower Silurian (Primordial), Jurassic, Cretaceous, and Teritary fossils collected in Nebraska by the exploring expedition nder the command of Capt. W. F. Reynolds, U. S. Topog. Eng., with some remarks on the rocks from which they were obtained: Acad. Nat. Sci. Phila. Proc., vol. 13, p. 433, 1862.

Montana and is continuously exposed over an area of nearly 25,000 square miles. It has been largely eroded along the principal rivers, and from the major uplifts, Bowdoin and Poplar domes, Cedar Creek anticline, and the northern extension of the Black Hills uplift in the southeastern part of the state. The only large area of Fort Union rocks in Central Montana, an area of over 1000 square miles in extent, is that of the Bull Mountain coal field, an elliptical synclinal basin, 50 by 30 miles. Smaller areas are also found underlying Pine Ridge, southeast of the Bull Mountain area; in the Red Lodge coal field, and in Crazy Mountains. The former area has been mapped as Lance by Rogers(14), but before the Lance and Fort Union beds were separated as definitely as they are today. Another small area of Fort Union rocks, less than 2 square miles in extent, has been mapped by Bowen(15), six miles east of Big Sandy in Chouteau county. Its presence in this locality, far removed from all other known areas of Fort Union rocks, is due to faulting, which has brought the beds down to the level of older rocks. It is, of course, possible that the coal bearing rocks of the St. Mary River formation and the overlying Willow Creek formation mapped by Stebinger(16) are in part the equivalent of the Fort Union, but the authors have preferred to map them as of Lance age.

The rocks of the Fort Union formation consist of coarse to fine grained, loosely to firmly cemented arkosic (feldspathic and micaceous) sandstones and sandy clays, and clay-shales in about equal amounts. Numerous lignite beds, which grade into sub-bituminous coal seams in Central Montana, occur throughout the formation. As a rule the sandstones are massive, fairly thick bedded, and of a light yellow color, and the clays are either dark or greenish gray, brownish, or nearly white, and where clinkered by the burning of underlying lignites are bright red. In general, therefore, the prevailing appearance of the Fort Union is in marked contrast to the more uniform, dull and somber appearing rocks of the Lance. In places, however, the lithologic distinction is not clear, the prevailing color of the Fort Union rocks being ash gray(17).

Concretions of spherical to cylindrical, log-like shapes are common, especially in the lower part of the formation. The concretions consist of more firmly cemented sandstone in the loosely cemented sandstones, and of calcareous and sideritic (iron carbonate) replacements in the shales. In a few places(18) in the sandstones are lenses of conglom-

(14) Rogers, G. Sherbune, Geology and coal resources of area southwest of Custer, Montana: Bull. 541-H, pp. 30-31, 1914.
(15) Bowen, C. F., Big Sandy coal field, Montana: U. S. Geol. Survey, Bull. 541-H, pp. 74-75, 1914.
(16) Stebinger, Eugene, Geology and Coal Resources of northern Teton County, Montana: U. S. Geol. Survey, Bull. 621-K, pp. 124-128, 1916.
(17) Stebinger, Eugene, Sidney lignite field, Montana: U. S. Geol. Survey, Bull 471, p. 285, 1912.
(18) Woolsey, L. H., and others, Bull Mountain coal field, Montana; U. S. Geol. Survey, Bull. 647, pp. 27, 1917, and Rogers, G. S., Little Sheep Mountain Coal field, Montana: U. S. Geol. Survey, Bull. 531-F., p. 11, 1913.

erate, consisting of shale and sandstone pebbles in a sandstone matrix. Many of the sandstones are locally laminated and cross stratified as a result apparently of depositions both from water and from wind. In the shales, many of which are calcareous, there are in places, many flakes and small crystals of gypsum, so that the weathered surface resembles in places the outcrop of the Bearpaw shales. In the Bull Mountain area there are also thin layers, 1 to 3 feet thick, of buff limestone(19).

The Fort Union formation is in most places readily subdivided into a lower part consisting largely of clay-shale, sandy shale, and soft sandstone, which has been called the Lebo shale member(20) and an upper part consisting chiefly of sandstones more massive and resistant than any of those found in the Lebo shale member. Over a large area in Central and the western portion of Eastern Montana, the Lebo shale contains a considerable amount of tuffaceous andesitic material, and it is on the basis of this and of stratigraphic position also(21) that correlation is made with the "Lebo shale andesitic member of the Fort Union," at the type locality northeast of Crazy Mountains.

In the extreme eastern part of the state there is little distinction in the lithology of the lower and upper parts of the Fort Union. Coal and lignite seams are found in both the Lebo shale and overlying sandstones, but few of the seams in the Lebo shale proper are of the best quality and in many places are merely carbonaceous shales(22).

The Fort Union rocks, at least south of the area covered by glacial drift, are well exposed. Where flat lying or nearly so, the sandstones form buttes, mesas, and terraces, terminated by scarps, 50 to 100 feet high. In places the sandstones weather into smooth rounded faces, but more commonly into fantastic forms and pinnacles with honey-combed surfaces. The shales weather into gentler and smoother slopes and rounded buttes, and in favorable places into badland topography. Where more steeply dipping, the sandstones form ridges or cuestas, between valleys cut in the less resistant shale.

Although local unconformities occur in most places, the Lance formation and the Lebo shale appear to be generally conformable and to represent virtually continuous deposition. The same is true of the contact of the Lebo shale with the overlying and much thicker part of the Fort Union formation, and therefore, although erosion has removed hundreds of feet from the top of the Fort Union, no significant amount of erosion has occurred during its accumulation. The Lebo shale is estimated to be from 200 to 300 feet thick, but as mentioned, thins out to nothing in the eastern part of the state. The

(19) Woolsey, L. H. and others, Bull Mountain coal field, Montana; U. S. Geol. Survey, Bull. 647, p. 28, 1917.

(20) Stone, R. W., and Calvert, W. R., Stratigraphic relations of the Livingston formation of Montana: Econ. Geology, vol. 5, p. 746, 1910.

(21) Rogers, G. S., Little Sheep Mountain coal field, Montana: U. S. Geol. Survey, Bull. 531-F., p. 15, 1913.

(22) Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Montana: U. S. Geol. Survey, Bull. 711-G, pp. 126-127, 1920.

Fort Union is variously estimated throughout Eastern Montana from 1000 to 1400 feet thick, but to the west it thickens. In the Bull Mountain area, where presumably the amount of erosion is greater than in Eastern Montana, the upper part of the formation alone is 1650 feet thick, and although the Lance and Fort Union formations do not appear to have been definitely separated in the Red Lodge and Crazy Mountains areas, yet the undoubted Fort Union rocks are at least 2800 feet in the former(23) and over 3000 feet in the latter area(24).

Detailed sections of the Fort Union are given in most of the United States Geological Survey publications dealing with Eastern Montana. One of the most instructive is the generalized section given by Calvert(25) of the Sidney lignite field.

The Fort Union contains a very large flora, approximately 500 species(26), generally acknowledged to be Eocene. It has a far less abundant fauna, consisting of fresh water shells, some vertebrates, and even small mammals, that is less generally believed to be Eocene. The plants and shells as well as the numerous coal seams indicate, however, that the Fort Union was deposited in fresh or nearly fresh water, presumably in inland streams and lakes, and possibly in estuaries.

Lance formation.—The name Lance formation, first used by Stanton(27) is an abbreviated form of the term "Lance Creek beds" used by Hatcher(28) to designate what had been previously called the "Ceratops beds" of the Laramie. Since Stanton's use of the term in 1910, all of the rocks underlying the Fort Union and overlying the Bearpaw shales or the Fox Hills sandstone have been called Lance, and none of the rocks of Central and Eastern Montana have any longer been referred to the Laramie.

The Lance formation outcrops so as to form a broad belt, 3 to 60 miles wide, averaging 25 miles wide, between the predominating Fort Union rocks of Eastern Montana and the predominating Mesozoic rocks of Central Montana. It is further exposed in Eastern Montana along the larger rivers and on the flanks of the larger uplifts, the Cedar Creek anticline and the northern extension of the Black Hills uplift, and at the crests of the smaller uplifts, like the Coal Creek dome, Scobey anticline, and Big Muddy Creek dome. In Central Montana, south of the Little Belt-Big Snowy anticlinorium, the formation

(23) Woodruff, E. G., Red Lodge coal field, Montana: U. S. Geol. Survey, Bull. 341, p. 94, 1909.
(24) Stone, R. W., Coal near the Crazy Mountains, Montana: U. S. Geol. Survey, Bull. 341, p. 82, 1909.
(25) Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey, Bull. 471, p. 199, 1912.
(26) Knowlton, F. H., Science, April 1, 1921, p. 307.
(27) Stanton, T. W., Fox Hills sandstone and Lance formation in South Dakota, North Dakota, and eastern Wyoming: Am. Jour. Sci., 4th ser., vol. 30, p. 172, 1910.
(28) Hatcher, J. B., Relative age of the Lance Creek beds of Converse County, Wyo., the Judith River beds of Montana, and the Belly River beds of Canada; Ann. Geologist, vol. 31, p. 369, 1903.

PLATE IV.—LANCE FORMATION.

A typical exposure of the Lance formation showing the white basal member, Colgate sandstone, and the overlying somber-colored shales and sands. Sec. 8. T. 19 N., R. 29 E.

is exposed around the flanks of the Bull Mountain syncline, and underlies the greater part of the synclinal area between the major anticlinal axis and the main front range of the Rocky Mountains. There are also a few small outliers between the two synclinal areas. North of the anticlinorium the Lance forms two synclinal areas, one south of the Little Rocky Mountains uplift and the other to the north, extending into Canada. Between the Sweetgrass arch and the main front range, the rocks of the St. Mary River and Willow Creek formations, referred by Stebinger(29) to the Tertiary(?) Eocene(?), and also the Horsethief formation of Cretaceous age, have been mapped by the authors as the equivalent of the Lance.

The Lance formation is composed of alternating beds of dull grayish to greenish yellow, soft to hard sandstones, greenish to gray sandy shale, drab, yellow, gray, and in a few places brown clays, and clay-shale. In most places the sandy rocks predominate and the prevailing dull neutral colors have given rise to the name "somber beds." West of the Sweetgrass arch, the St. Mary River formation is chiefly maroon to chocolate brown in color, so that the formation has a predominating brownish red appearance, due partly to the covering of red soil.

The sandstones are noticeably harder, coarser grained, even arkosic and conglomeratic in places, and more massive in the lower part of the formation. In the upper part there are numerous carbonaceous layers and a few relatively thin and non-persistent seams of impure lignite and high-ash coal. At least in the northeastern and northwestern parts of the Lance area in Montana there are a few relatively thin lentils of impure limestone(30). The sandstones, particularly the lower and more massive ones, are cross bedded and ripple marked, and contain numerous dark brown, iron stained concretions, some spherical and rounded, others cylindrical and log-like up to large sizes, 3 feet in diameter and 20 to 30 feet long.

Although the Lance formation in most places is readily divided into three subdivisions, a lower part consisting chiefly of massive sandstone, a middle part of alternating clays and soft sandstones, and an upper carbonaceous or lignitic part, yet it was not feasible to make the subdivision during rapid reconnaissance mapping. The lower massive sandstones contain in several places an undoubted Cretaceous marine fauna and are best considered as of Fox Hills age. Fox Hills beds have been definitely determined bordering the Cedar Creek anticlicle just east of the Montana line in North and South Dakota(31), but the same beds have been included in the Colgate sandstone mem-

(29) Stebinger, Eugene, Geology and coal resources of northern Teton County, Montana: U. S. Geol. Survey, Bull. 621-K, p. 124, 1916.
(30) Smith, C. D., The Fort Peck Indian Reservation lignite field, Montana: U. S. Geol. Survey, Bull. 381-A, p. 43, 1910, and Stebinger, Eugene, Op. Cit. p. 27.
(31) Winchester, D. E., et al., The lignite field of northwestern South Dakota: U. S. Geol. Survey, Bull. 627, pp. 17-18, 1916.

ber of the Lance formation in Montana(32). The sandstones and shales overlying the Bearpaw shales along the Missouri River north of Jordan, have also been referred to the Fox Hills sandstone by Leonard(33).

In the upper Musselshell Valley, an assemblance of andesitic sandstones and dark shale between the Bearpaw and Lance formations has been designated as the Lennep sandstone(34). The fossil shells found in the formation are about equally fresh, brackish water, and marine, and are more closely related to the Cretaceous than to the Tertiary. It occupies the stratigraphic portion of the Fox Hills and has been included in this report with the other basal members of the Lance.

In the northeastern part of Central Montana, the Horsethief sandstone overlies the Bearpaw shale and underlies the Tertiary(?) formations. It consists chiefly of a sandstone, which becomes shaly toward the base, and to the south near Augusta, contains some conglomerate with well rounded pebbles of fine grained igneous rock. In places the sandstone is exceedingly fossiliferous, some beds being almost entirely composed of oyster and other shells. The fauna is Cretaceous and of both brackish water and true marine, although near-shore types(35). This formation has also been included in this report with the other basal members of the Lance.

The upper lignitic portion of the Lance is doubtless best correlated with the Ludlow lignitic member of the Dakotas(36). However, in reconnaissance mapping, as already mentioned, the contact between the Lance and Fort Union, where not marked by the Lebo shale was placed at the contact of the beds of dull and bright colors, or at the lowest persistent coal seam, both of which vary considerably in position. As a result, most of the beds in Montana of the same horizon as the Ludlow lignitic member have been placed in the Fort Union.

Like the Fort Union rocks, those of the Lance formation are well exposed south of the area covered by glacial drift. Furthermore, where flat lying, the sandstones form buttes, mesas, or series of scarps, 50 to 100 feet high, whereas, the shales weather into smooth, gentle slopes and rounded buttes, and in favorable places into bad land topography. Where more steeply dipping, the sandstones form cuestas and hogbacks, separated by narrow valleys cut in the soft shales.

The basal sandstone of the Lance formation is thickest near the mountains and thins slightly to the east. In the northwestern

(32) Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey, Bull. 471, pp. 189 and 194-195, 1912.
(33) Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geol., vol. 19, p. 515, 1911.
(34) Stone, R. W., and Calvert, W. R., Stratigraphic relations of the Livingston formation of Montana: Econ. Geol., vol. 5, p. 746, 1905.
(35) Stebinger, Eugene, The Montana group of northwestern Montana: U. S. Geol. Survey Prof. Paper 90-G, p. 62, 1914.
(36) Winchester, D. E., et al., The lignite field of northwestern South Dakota: U. S. Geol. Survey, Bull. 627, pp. 19-22, 1916.

part of Central Montana the Horsethief sandstone varies from 250 to 400 feet thick. In the upper Musselshell Valley, the Lennep sandstone is 315 feet thick. Farther east the Colgate and Fox Hills sandstone varies in thickness from 50 to 200 feet. In like manner the upper part of the Lance thins eastward, but more noticeably. Along the mountain front, the upper Lance varies from 1400 to 1700 feet thick. It thins so rapidly to the east that it is 700 to 800 feet thick in east Central Montana, 500 feet in southeastern Montana, and only 200 feet thick in northeastern Montana.

Detailed sections are given in nearly all of the United States Geological Survey publications dealing with the Lance formation, but vary so from place to place that they are of little value in a general description.

The Lance formation like the Fort Union, contains a rich flora, comprising about 125 forms, of which 87 species(37) have been positively identified. Invertebrate fossils are not numerous except in the basal marine beds. On the other hand, numerous fossil vertebrates, the most striking of which si the large three-horned **Triceratops**, have been found. It is quite certain that in places a portion of the basal beds seem to have been deposited in fresh or brackish waters. Cross bedding and ripple marks indicate deposition by streams and in places, even by wind. In Montana the upper beds appear to have been entirely of continental or fresh water origin, having been deposited in streams, lakes and possibly estuaries.

(37) Knowlton, F. H., Science, p. 307, April 1, 1921.

MESOZOIC AND PALEOZOIC SYSTEMS

BY

ARTHUR BEVAN

Since it is the purpose of this part of the report to present the principal features of the Mesozoic stratigraphy of the Montana Great Plains the observations of the writer and other members of the State Bureau of Mines' field parties have been rather freely supplemented by the use of data from the published reports upon the region. Numreous publications have appeared, mainly from the United States Geological Survey, which treat of particular districts, although a few discuss stratigraphic units, but so far the great body of data afforded by the many field studies have not been conveniently assembled. Although the Mesozoic formations are here discussed in some detail the treatment is by no means exhaustive. The Paleozoic formations, in so far as they appear in this province, are discussed briefly with reference to the features that have a bearing upon the petroleum resources of the state. The articles which have been consulted are listed in the bibliography, and foot-note references to sources are made wherever appropriate.

THE MESOZOIC

Formations of Mesozoic age appear at the surface or underlie the surficial mantle of alluvium and glacial drift throughout approximately half of the Great Plains province in Montana. They cover all the area north of the Missouri River from the Rocky Mountains to Eastern Montana, with the exception of limited areas of Lance sediments adjacent to the mountain front, igneous rocks in the Bearpaw Mountains, the Sweetgrass Hills, and the Little Rocky Mountains, and Paleozoic sediments in the last two uplifts. The area between Missouri River on the north, Rocky Mountains on the west, and Musselshell and Little Bighorn rivers on the east is occupied mainly by Mesozoic sediments. A broad tongue reaches southeast from this area in the vicinity of Mosby on Musselshell River into Yellowstone Valley west of Forsyth, while a parallel embayment of Lance and Fort Union rocks extend northwest from this point through Bull Mountains and across Musselshell Valley beyond Roundup. Another broad area of Lance and Fort Union formations covers the Mesozoic along the Rocky Mountain front from the Crazy Mountains to the Wyoming boundary. Elsewhere in this part of the state the surface continuity

of the Mesozoic is interrupted only by the isolated mountain uplifts, scattered outliers of younger sediments, or a relatively thin mantle of unconsolidated materials.

The Mesozoic group is now commonly separated into four subdivisions: The Triassic, Jurassic, Comanchean, and Cretaceous systems, all of which are present in the plains portion of the state(38). In this region it includes the formations that are between the Quadrant formation below and the Lance formation above. The Triassic is meagerly present, being restricted to the flanks of the Bighorn and Pryor mountains, where it consists of the Chugwater formation, or "Red Beds." The Ellis formation, which is the main representative of the Jurassic system, is exposed only along the borders of the several mountain uplifts in Central Montana. It is overlain and paralleled in outcrop by the Morrison formation which appears to be transitional between the Jurassic and Comanchean systems. The latter is represented mainly by the Kootenai formation which has a surface distribution similar to that of the Ellis formation but has a wider outcrop due to its greater thickness and gentler dips. Overlying it is the Colorado shale of Cretaceous age, with vast areal extent in the Sweetgrass arch, and less extensive exposures in several of the major uplifts. The remaining formations of this system are included in the Montana group and consist of the Eagle sandstone at the base, the Claggett formation, the Judith River formation, and the Bearpaw shale. These formations, or their equivalents, occupy a considerable part of Central Montana. In the northwestern portion the upper part of the Eagle sandstone and the other formations below the Bearpaw shale are included in the Two Medicine formation. The Livingston formation, which is partly of undoubted Cretaceous and partly of Lance age, borders the Crazy Mountains and extends southeasterly beyond the Yellowstone Valley.

The Mesozoic formations are very largely composed of clastic sediments, mainly sandstones and shales, of which the latter are greatly preponderant. A striking feature of the sequence is the alteration of shale and sandstone formations, each of which has persistent lithologic homeogeneity. As a rule pronounced intercalation of the one kind of sediment in the other is rare except in a few places. Thin limestones occur sparingly but are mainly confined to the Ellis formation with local lenses and thin beds in the Kootenai formation. Coal is widespread and abundant in some of the formations, especially in the Kootenai, although workable beds are present in several places in the Eagle, Judith River, and Two Medicine formations. The Chugwater formation contains thick gypsum beds at several localities. Igneous material is present in the Mesozoic group only in the form of tuffaceous beds intermixed with variable amounts of sediment at several horizons, chief of which is the Livingston formation.

(38) Comanchean is here used as the equivalent of the former "Lower Cretaceous" in accordance with the prevailing current usage.

Inasmuch as the different formations vary in thickness from place to place throughout the state as well as being either partially removed by erosion or deeply buried in any particular area, it is somewhat difficult to estimate the total thickness of the Mesozoic sediments. However, it may be roughly placed between 2400 feet as a minimum and 8800 feet as a maximum. This includes all the Mesozoic formations of sedimentary origin no matter how widely separated the most complete or the thickest sections may be. The thickest more or less continuous sections that have been measured are in northwestern part of Central Montana, in the vicinity of Bighorn Mountains, and in Musselshell Valley, where a total of 7000, 5700, and 4700 feet respectively have been reported(39).

THE CRETACEOUS SYSTEM.

Formations of Cretaceous age occupy by far the greater part of the vast area over which Mesozoic sediments constitute the surface formations. The only places where older rocks crop out are in the mountain uplifts and over rather limited tracts adjoining a few of them.

The subdivisions of the Cretaceous system (as the term is here used) in the northern Black Hills and the adjacent Great Plains are as follows: Dakota sandstone at the base, Benton group, Niobrara formation, and Pierre shale(40). Farther north in South Dakota the Pierre is overlain by the Fox Hills sandstone which constitutes the youngest formation of positive Cretaceous age in this province. Some of the early surveys in mapping the Cretaceous formations of the Rocky Mountains and the bordering Great Plains of Montana used the divisions, Dakota, Colorado, and Montana, although the term Benton was widely used for the shales above the so-called Dakota sandstone.

Recent extensive detailed examination by the U. S. Geological Survey of many Cretaceous areas in the state has apparently demonrtsated beyond reasonable question that the Dakota sandstone is nowhere present in this state. Thus it is erroneous and misleading to call any beds in Montana the "Dakota sandstone"(41). Inasmuch as the Niobrara can not be recognized in Montana as a distinct unit and the section between the Kootenai and the basal Montana includes more than the typical Benton group the use of the latter term has become inappropriate. It has therefore been supplanted by the Colo-

(39) Stebinger, Eugene, Geology and coal resources of northern Teton County, Montana: U. S. Geol. Survey, Bull. 621-K, p. 124, 1916; Hares, C. J., unpublished data, and Darton, N. H., Geology of Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, Plate VI, 1906; and Reeves, Frank, Press Report U. S. Geol. Survey, 1921.

(40) Darton, N. H., and O'Hara, C. C., U. S. Geol. Survey Geol. Atlas, Aladdin folio(No. 128), 1905.

(41) The same criticism probably applies to the Cretaceous classification of southern Alberta, where the term "Dakota" has persisted from the early surveys. See Stebinger, Eugene, U. S. Geol. Survey, Bull. 641-C, pp. 61-62, 1916.

rado for the lower part of the Cretaceous section. The Montana group of this state appears to be the equivalent of the Pierre of South Dakota and may include also the Fox Hills sandstone of that region. Hence at the present time the two-fold division of the Cretaceous into the Colorado shale and the Montana group is accepted for Montana. The Montana group has been further subdivided throughout the state, and these divisions are discussed below.

THE MONTANA GROUP.—The Montana group includes all formations of undoubted Cretaceous age above the Colorado shale. The term was first applied by Eldridge to the Fort Pierre and Fox Hills formations near Denver, Colorado(42), and later to the similar section in the Bighorn Basin in northwestern Wyoming and southern Montana(43). Throughout the greater part of the region this group consists of Eagle sandstone at the base, Claggett formation, Judith River formation, and Bearpaw shale, each of which forms a distinct lithologic unit. The Claggett and Bearpaw, however, are so nearly identical in many places that they can be distinguished only by noting the stratigraphic sequence. There is no difficulty in doing this if the prominent Lance sandstones are taken as a datum plane, or if the Colorado shale and Eagle sandstone are recognized. The Eagle and Judith River sandstones are somewhat dissimilar but may be mistaken for each other in areas of obscure outcrops. The best method, then, of identifying the several formations of this group is to note the succession carefully. Where the strata are steeply dipping this can be done by a glance at the topography, as the Claggett and Bearpaw will then occupy conspicuous depressions between prominent sandstone ridges. These sandstones are invaluable aids in deciphering the structure of many areas, for the shales of this group seldom exhibit bedding clearly.

With a change in the nature of the sediments in the northwestern part of Central Montana the divisions of the Montana group become Virgelle sandstone, Two Medicine formation, and Bearpaw shale. In this section the Virgelle and the overlying Horsethief are the best key horizons. These two sandstones are nearly identical in composition and appearance but they can be readily distinguished by means of their distribution and stratigraphic relations.

In some areas it is almost impossible to identify with certainty any particular division of the Montana group owing to the meager and widely scattered outcrops of formations which change markedly in lithology within short distances. The difficulty is greatly increased by the existence of complex structure, due to pronounced folding or faulting, which has been generally concealed by widespread deposits of glacial drift or terrace gravels. Such tracts exist at several places,

(42) Eldridge, G. H., Method of grouping the formations of the Middle Cretaceous: Am. Jour. Sci., 3d ser., vol. 38, pp. 313-321, 1889.

(43) Eldridge, G. H., A geological reconnaissance in northwest Wyoming: U. S. Geol. Survey, Bull. 119, pp. 23-24, 1894.

chiefly in the northwestern part of Central Montana. For mapping purposes the problem has been solved by designating such areas as "Montana undivided." There are a few other areas, as in the Bighorn Basin, where the typical characteristics of the individual formations change to such an extent that the Montana group can not be subdivided without a detailed survey of the region. The term "Montana undivided" is likewise used here in mapping the entire group or such part of it as may be present.

The thickness of the Montana group is so considerable that it can not be determined readily at a single locality or even in a small area. Complete sections that have been measured along the northwest side of Elk Basin and near Bridger, in Carbon County, where the group appears to be the thinnest, give a thickness of 1185 and 1069 feet respectively(44). A more recent measurement of the formations in Elk Basin gives a thickness of approximately 1815 feet to the Montana, but it appears that the summit of the Bearpaw has been taken at a higher horizon(45). A generalized section shows a thickness of 1750 feet in Lake Basin, 2000 to 3050 feet in Musselshell Valley, 2050 to 2275 feet in Phillips County, and 3020 feet in Glacier County.

Bearpaw shale.—The name Bearpaw shale was first applied to the thick body of shale that forms the upper part of the Montana group on the flanks of the Bearpaw Mountains(46). As a result of its stratigraphic position and the widespread erosion of younger formations it probably has a greater areal extent than any other Mesozoic formation. It is continuously exposed over thousands of square miles in the east- and south-central parts of the state and is present immediately beneath the mantle of glacial drift over a vast area north of the Missouri River. It is exposed along the valley of the lower Musselshell River and from there southeastward to the Porcupine dome. Another extensive area exists in Lake Basin northwest of Billings from which it crosses Yellowstone Valley east of Huntley and stretches southward between the Bighorn and Little Bighorn rivers. In the northwestern part of the region it occurs on the west flank of the Sweetgrass arch. The broad expanse of Lance and Fort Union in the eastern part of the state is undoubtedly underlain by it, as is shown by the belt of Bearpaw shale that surrounds the Porcupine dome, the belt of similar shale (Pierre) along the axis of the Cedar Creek anticline, southeast of Glendive, and the extensive area in southeastern Montana.

Throughout the greater part of the area which it occupies the Bearpaw shale rests upon the Judith River formation, but in the

(44) Fisher, C. A., Southern extension of the Kootenai and Montana coal bearing formations in northern Montana: Econ. Geol., vol. 3, pp. 94-96, 1908.

(45) Section measured by C. J. Hares and quoted by E. T. Hancock, U. S. Geol. Survey, Bull. 691, p. 1, XVII, 1918.

(46) Stanton, T. W., and Hatcher, J. B., Scence, new ser., vol. 18, p. 212, 1903. See also, U. S. Geol. Survey Bull. 257, p. 13, 1905.

northwestern part of Central Montana it overlies the Two Medicine formation(47). In the latter area it lies beneath the Horsethief sandstone; in the Musselshell Valley from Lavina westward it is immediately below the Lennep sandstone; while elsewhere it underlies the Lance formation.

The Bearpaw shale is typically a dark gray, clayey shale that weathers into a distinctive alkaline, infertile gumbo soil. Small crystals and crystalline flakes of gypsum are abundant throughout the formation, being especially noticeable upon the weathered slopes. In consequence of the abundance of gypsum, water from the formation is commonly too alkaline for domestic use. Concretions of dark gray, fine-grained limestone are sparsely scattered through the shale in most places but in places they are grouped in bands or zones. They weather reddish-brown on the surface and after long exposure crumble to a scattered mass of small angular fragments which somewhat protect the shale at that place from erosion. Many of these concretions contain much sideritic calcite, and cone-in-cone structure is rarely present. As a rule they are one to two feet in diameter but some as large as 12 to 15 feet have been reported southeast of Havre(48).

In some districts the Bearpaw becomes distinctly sandy either in zones or throughout most of the formation and thus, to a greater or less extent, loses its characteristic lithologic nature. One phase of this change is well shown in the Lake Basin field(49). Here several sandstone beds appear at various horizons and form conspicuous ledges and gentle dip-slopes that break the monotony of the subdued topography that is generally developed on the shale. Sandy shales and sandstones are especially prominent as the adjacent formations, particularly the Judith River, are approached, but occur in some localities well within the main mass of typical Bearpaw shale. These sandstones are commonly yellowish though locally a layer is white. They are rather coarse-grained with local thin conglomerates, as a rule strongly cross-bedded, and contain plentiful plant remains in a more or less fragmentary condition. Some of the sandstones in many places weather into great numbers of conspicuous, hard, flattish, rusty concretions. A notable peculiarity in certain portions of Lake Basin is the occurrence of andesitic sandstones that cap long narrow ridges. Subordinate amounts of tuffaceous material are present at various horizons. Another noteworthy feature here is carbonaceous shale which passes locally into beds of lignite about a foot thick. There is considerable lateral variation in this field in the nature of the sediments, even in short distances, sandstones frequently giving way to typical clay shale in the same ridge or a thick section of dominantly sandy beds in one

(47) The upper part of the Two Medicine formation is equivalent to the Judith River formation.

(48) U. S. Geol. Survey Bull. 257, p. 48, 1905.

(49) Hancock, E. T., Geology and oil and gas prospects of the Lake Basin field, Montana: U. S. Geol. Survey Bull. 691-D, 1918.

place may be replaced near by with a sequence of interbedded thin sandstones and thick shales.

The sandy phase of the Bearpaw is exhibited west of the Lake Basin district between Harlowton and Big Timber and in Yellowstone Valley west of Columbus. In this region the sandstones become so preponderant that it is only by careful tracing of the formation from its typical development east of here that it can be separated from the underlying Judith River or the overlying Lance. Farther west and southwest the strata are entirely of sandstone and pass into the so-called Livingston formation, from which the Bearpaw can be differentiated, if at all, only by persistent detailed work.

A somewhat similar change takes place in the northwestern part of Central Montana in the vicinity of Dupuyer Creek in southern Pondera County. The Bearpaw is typically developed north of here to far beyond the Canadian boundary while to the south the "dark shale grades within a short distance into light-colored sandstones and clay shale that are identical with the prevailing materials in the Two Medicine formation and south of Dupuyer Creek can not be separated from that formation"(50).

Typical exposures of the Bearpaw are abundant throughout the area where it appears at the surface but owing to the fact that it weathers readily extensive sections are rare. This seeming defect is counterbalanced by the homogeneity of the formation from top to bottom in its typical development, and thus almost any cut bank in it gives a good idea of the whole formation. Several detailed sections of the sandy phases are given by Hancock in the Lake Basin field(51). A complete section is shown on the south flank of an anticline along the Harlowton-Big Timber road in the southwestern part of T. 15 E., R. 6 N. Other complete sections which include the entire underlying Judith River and Claggett formations are readily accessible along the steeply dipping south limb of the Devil's Basin anticline, northeast of Roundup.

In consequence of the universal occurrence of the typical Bearpaw between two prominent sandstone formations, the common topographic expression of the much weaker shale is a marked depression bounded by conspicuous dip slopes or escarpments. This is especially true where the dip is steep, as south of Lavina, in Musselshell (now Golden Valley) County. Where the strata are horizontal or nearly so the Bearpaw area is generally a monotonous expanse of low rounded ridges and hills beyond the base of a more or less prominent Lance escarpment. Resistant sandstones give rise in places to ridges and long dip slopes within the formation but these are exceptional outside of the Lake Basin district.

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(50) Stebinger, Eugene, Oil and gas geology of the Birch Creek-Sun River area, Northwestern Montana: U. S. Geol. Survey Bull. 691-E, p. 166, 1918.

(51) Hancock, E. T., Geology and oil and gas prospects of the Lake Basin Field, Montana: U. S. Geol. Survey Bull. 691-D, pp. 121-123, 1918.

The thickness of the Bearpaw has been measured at various places throughout the state. It is reported in the northwestern part of the region to have a total thickness of 500 feet which increases to 1000 feet in Valley County and reaches a maximum of 1150 feet in eastern Fergus County. Southward from here the formation gradually decreases to about 500 to 600 feet in Yellowstone Valley and to 130 feet in the northern part of Elk Basin.

The Bearpaw contains an abundant fauna, about fifty species of marine invertebrates having been identified from various collections in it. Most of the fossils occur in the calcareous concretions and become very conspicuous as these masses crumble upon exposure to the weather. Wherever these weathered concretions are present, a few specimens can nearly always be found and on many slopes several species can be collected in a few moments. Such a place is about six miles north of Melstone in Sec. 36, T. 11 N., R. 30 E. Other typical localities with representative lists of fossils collected therefrom are given in several previous reports(52). Of these numerous forms, among the most characteristic are **Baculites compressus, Baculites ovatus,** and **Scaphites nodosus,** but species of **Inoceramus, Mactra, Ostrea,** and **Placenticeras** are common. This invertebrate fauna is very similar to that of the underlying Claggett shale but differs in that the fossils are more abundant and the species are more diverse. Of 32 forms listed by Bowen from the Bearpaw only ten are present also in the Claggett. A few fossils other than invertebrates have been found in some parts of the state. Scattered remains of skeletons of gigantic marine reptiles have been collected in the western part of Valley County(53).

E. T. Hancock reports an abundance of **Halymenites,** petrified wood, and stems and leaves of plants from the sandstones and associated carbonaceous shales in the Bearpaw of Lake Basin(54).

Judith River formation.—Except in the northwestern part of the Great Plains province the Bearpaw shale is everywhere underlain by a series of sandstones and shales which has long been known as the Judith River formation. This name was originally applied by F. V. Hayden in 1871 to typical exposures of these strata near the mouth of Judith River(55), but it was not until more than thirty years later that the proper position of the formation as a member of the Montana group was definitely determined(56). Since then there has been considerable discussion in regard to the exact horizon of

(52) U. S. Geol. Survey Prof. Praper 90-I, p. 102; Prof. Paper 120-B, p. 30; Bull. 647, p. 21.
(53) Collier, A. J., Geology of northeastern Montana: U. S. Geol. Survey Prof. Paper 120-B, p. 30, 1918.
(54) Op. cit. pp. 121-122.
(55) Hayden, F. V., Geology of the Missouri Valley: U. S. Geol. Survey Terr. Prelim. (Fourth Ann.) Rept., p. 97, 1871.
(56) Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, 1905.

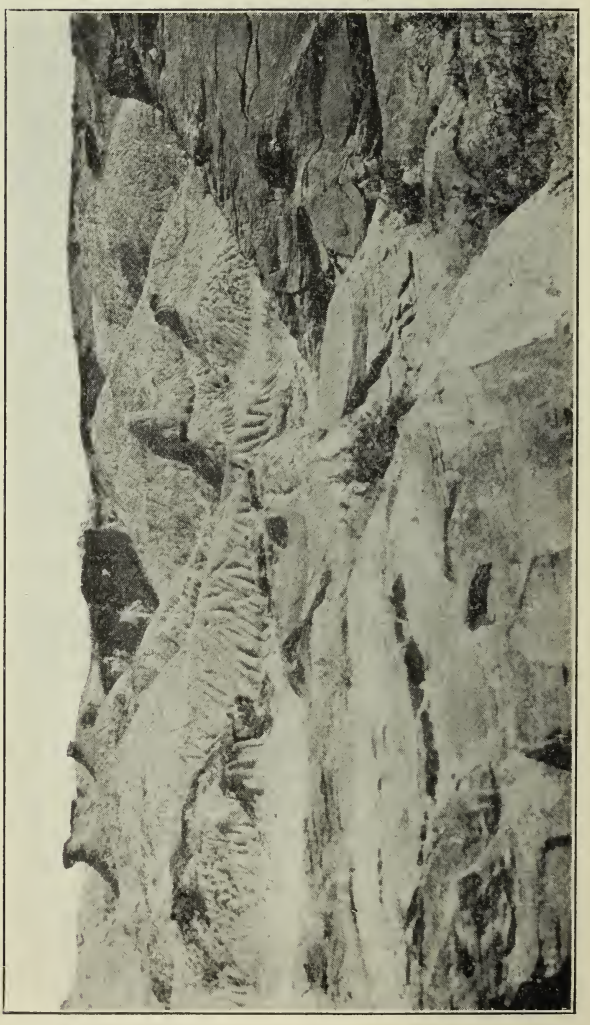

PLATE V.—JUDITH RIVER FORMATION.

Badlands developed in the flat-lying Judith River formation on Rattlesnake Creek, T. 27 N., R. 21 E.

these beds but much recent detailed work has confirmed the earlier conclusions(57).

The areal extent of the Judith River is much more restricted than that of the Bearpaw. Its distribution north of Missouri River is considerably obscured by the widespread mantle of glacial drift but the numerous streams have cut sufficiently deep in many places to expose the formation on the valley slopes. An irregular belt of it several miles wide encircles the Bowdoin dome, from which a broad belt extends westward far up Milk Valley beyond Havre toward the Canadian boundary. Other branches which reach southward from various points along Milk River surround the Bearpaw and Little Rocky mountains before uniting in the broad embayment that occupies Missouri Valley for about fifty miles below the mouth of Judith River. The main outcrop of the formation continues south along the east side of Judith Valley and, growing rapidly narrower as the North Moccasin and Judith mountains are approached, swings sharply around their north slopes. Here it strikes southeasterly as a very narrow band along the north limb of the Cat Creek anticline, then swings around the east ends of the plunging Cat Creek, Flatwillow, and Devil's Basin anticlines, and continues west along the steep southern limb of the latter. It is exposed at several places south of the Big Snowy and Little Belt mountains and on the flanks of numerous local uplifts in Musselshell Valley as far west as Martinsdale. From this valley is continues in a southeasterly direction along the north side of Lake Basin, crosses Yellowstone River between Billings and Huntley, occupies Bighorn Valley in the vicinity of Hardin, then swings south along the east side of the Bighorn uplift to the Wyoming boundary. A branch of this belt swings around the east end of Lake Basin, crosses Yellowstone River a few miles west of Park City, and follows the west side of Bighorn Basin southward. The Judith River is the surface formation in the Ingomar and McGinnis Creek domes and forms the prominent encircling escarpment of the broad Porcupine dome. It also surrounds the northern extension of the Black Hills uplift.

The Judith River formation consists of a series of alternating sandstones, shales, and coal beds which vary greatly in relative proportions and sequence from place to place. In the northern part of the region the sandstones are commonly soft and friable, although locally quite hard, light gray to yellowish, thin-bedded to massive, and contain numerous iron and sandstone concretions, which are more abundant in the basal portion of the formation. The sandstones locally are distinctly cross-bedded and ripple-marked. The intercalated shales are predominantly clayey and as a rule are colored with tints of light gray or brown. With the appearance of dark gray to blackish colors thick beds of the clay shale may closely resemble the Bearpaw shale

(57) Bowen, C. F., The stratigraphy of the Montana group: U. S. Geol. Survey Prof. Paper 90-I, 1915.

but the lack of characteristic concretions and the presence of thick sandstones render the discrimination less difficult. An oyster bed composed of shells and fragments of **Ostrea subtrigonalis** is a common feature near the top of the formation in many places, and where present forms an excellent horizon marker. Coal beds are prominent in some areas, such as in Milk River Valley between Havre and Harlem, east of Big Sandy, on the northeast side of the Bearpaw mountains, and along the Missouri. The Judith River formation contains most of the coal of this section of the state, but some is present in the Eagle and in a small tract of Fort Union east of Big Sandy. The most persistent bed is near the top of the formation, just below the oyster bed, but as a rule the coals exhibit the same lateral inconstancy as the sandstones and shales so that they may grade into clastic sediments within short distances.

The remarkable lack of lateral persistence of these beds in the original area is clearly pointed out by Stanton and Hatcher(58) in their excellent discussion of the geology of this formation. They state:

> The frequency with which the different strata of sandstones and clays replace one another, both laterally and vertically, together with the great disturbances that have taken place subsequent to the deposition of the Judith River beds, renders it extremely difficult, if not impossible, to fix upon any definite horizons or strata within the limits of the fresh-water series that may be followed and recognized with certainty, even in reasonably adjacent sections. A detailed section taken at any point is of little value, since a similar section made at a distance of only a mile or two would give a quite different sequence of the alternating strata of sandstones and shales.

Although similar conditions apparently exist along the Missouri and throughout the area north of it, in areas farther south the lithology is more constant. In the Porcupine dome the formation is composed of massive light-gray sandstones at the top and base with intervening grayish shales. In Musselshell Valley it consists of three fairly well-defined members: a lower massive, cross-bedded, gray to brown sandstone; a gray to buff clay shale with interbedded sandstones; and an upper series of alternating sandstones and shales with some carbonaceous shale and coal. The sandstones become markedly andesitic toward the Crazy Mountains as is evidenced by the greenish color of the fresh rock and the presence of fresh feldspar and quartz crystals in thin sections. The middle member contains considerable petrified wood and dinosaur bones, while the osyster-bearing horizon is present near the top of the uppermost member(59). This three-fold division is clearly exhibited by the steeply dipping beds between Lavina and Broadview. Coal seams are locally present in this part

(58) Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, p. 34, 1905.

(59) Bowen, C. F., Anticlines in a part of the Musselshell Valley: U. S. Geol. Survey Bull. 691-F, pp. 191-192, 1918.

of the state but as a rule they are thinner and much less common than in the northern portion.

South of Yellowstone Valley in Carbon County the Judith River becomes a part of the thick series of sandstones that overlies the Colorado shale. It can be readily traced from the north to its crossing of the river east of Columbus but south of here it is included in the "Montana undivided."

On the east flank of the Bighorn uplift the Judith River sandstone can be traced to the Wyoming boundary where it is correlated with the Parkman sandstone.

In the northwestern part of the plains province the Judith River loses its identity through a change in color and character and grades into the Two Medicine formation(60). It can be recognized as far west as Milk Valley several miles above Havre.

The topography of the Judith River formation nearly everywhere is quite distinctive. The massive, more or less firm, sandstones, in flat-lying beds, produce bold cliffs and ledges which are in conspicuous contrast with the soft shales of the overlying Bearpaw and the underlying Claggett. Extensive bad lands have been developed in many places, as in the vicinity of Havre and east of Rattlesnake P. O. Where the strata are considerably tilted the entire formation has been etched by erosion into a series of alternating hogback ridges and narrow depressions. The sandstones commonly form prominent escarpments in the domes, which are especially conspicuous if the underlying shales are exposed. Fine examples of these "Keys to the structure" are exhibited by the Porcupine and Ingomar domes, as well as by portions of several other anticlines.

Typical sections of the Judith River are exposed in many deep valleys, among the best of which are those exhibited in the steep slopes along the lower Judith River and down Missouri Valley for several miles. The exposures are especially fine on the south side of the river, in the area of sharp relief known as "Breaks of the Missouri." Excellent sections may also be observed on the steep limbs of several anticlines in Musselshell Valley, as the south flank of the Devil's Basin anticline and the east side of the Broadview dome. Many exposures occur in the vicinity of Havre, on the south and west sides of the Little Rocky Mountains and in the Bowdoin dome, but none of these afford complete sections.

A detailed section for the Lake Basin field about eleven miles northwest of Billings is reported by Hancock in U. S. Geological Survey Bulletin 691-D, page 118, while another a few miles southeast of Huntley is given by him in Bulletin 711-G, page 123.

The thickness of the Judith River is fairly constant throughout the greater part of the region, but it thins rapidly as its eastern limit is approached. It is estimated to be 400 to 425 feet thick in the

(60) Stebinger, Eugene, The Montana Group of northwesstern Montana: U. S. Geol. Survey Prof. Paper 90-G, 1914.

Bowdoin dome, about 480 feet near Havre, and 600 feet in the western part of Musselshell Valley. Northwest of Billings it is reported to be nearly 400 feet thick and southeast of Huntley 500 feet thick, but it decreases to 125 feet in the northern part of the Porcupine dome, and still farther east is even thinner.

The Judith River contains an abundance of fossils of considerable variety, including about fifty known species of invertebrates, a similar number of vertebrates, and an extensive flora(61). Formerly all the known forms were brackish, fresh-water, and land types, but marine fossils have been discovered recently. Marine invertebrates are dominant on the northeast side of the Bowdoin dome (T. 33 N., R. 37 E), where the few fresh-water shells (Unios) are confined to the middle of the formation(62). An abundance of the marine seaweed, **Halymenites**, and some marine shells are present on the north side of the Porcupine dome (Sec. 8, T. 12 N., R. 38 E)(63). This fossil seaweed is also very plentiful several miles north of Billings, but farther west in Lake Basin, brackish-water mollusca, leaves, and bones of land animals are the only fossils yet discovered.

Claggett formation.—The Claggett formation, or Claggett shale as it may be called in some areas, is the thick mass of shale or shale and sandstone that is present between the Judith River formation above and the Eagle sandstone below. The name was given by Stanton and Hatcher, in their division of the Montana group, to the section in the vicinity of old Fort Claggett (now Judith) at the mouth of Judith River(64). The areal distribution of the Claggett is very similar to that of the overlying formation except that in the Milk River drainage it is present only in the Bowdoin dome, in a limited area on the northeast side of the Bearpaw Mountains, and from the vicinity of Big Sandy northward beyond the Great Northern Railway. It is exposed in the Ingomar dome but not in the McGinnis Creek dome. It apparently continues below younger formations to the eastern border of the state, and is exposed in the Black Hills uplift.

The Claggett exhibits marked changes in lithology in crossing the state from east to west. In the Bowdoin dome it consists of a dark gray, clayey shale which forms a typical gumbo soil and contains numerous large limestone concretions. Flakes of gypsum which are plentifully scattered throughout the shale, give an alkaline character to nearly all the water from the formation. The same characteristics

(61) For an excellent recent discussion and tabulation of the fauna see C. F. Bowen, Stratigraphy of the Montana group: U. S. Geol. Survey Prof. Paper 90-I (1915). The flora and fauna have both been described by Stanton and Hatcher, Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257 (1905).

(62) Collier, A. J., Geology of northwestern Montana: U. S. Geol. Survey Prof. Paper 120-B, pp. 28-29, 1918.

(63) Bowen, C. F., Gradations from continental to marine conditions of deposition in central Montana during the Eagle and Judith River epochs: U. S. Geol. Survey Prof. Paper 125-B, p. 15, 1919.

(64) Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. p. 13, 1905.

exist on the slopes of the Little Rocky Mountains, and in the upper part of the Colorado-Claggett sequence in the Porcupine dome. In all these areas the Claggett is so nearly identical with the Bearpaw that it is recognized mainly by its stratigraphic position. In some places the concretions of the older formation have a well-developed cone-in-cone structure which is a feature that appears to be seldom present in the otherwise identical concretions of the Bearpaw.

In the type area the Claggett is composed of two facies—a typical lower shale member several hundred feet thick, and a thinner upper one of sandstone and shale. This two-fold division persists in variable degree for a considerable distance to the north and south of this locality.

The gradual increase in the proportion of sand from east to west is nowhere more clearly shown than in Musselshell Valley(65).

The Claggett is identical in appearance with the Bearpaw in the eastern part of the valley but near the western border of Musselshell County two thin sandy zones appear. Within 20 miles to the west the sandstones compose half of the formation, while still farther toward the Crazy Mountains the formation merges into the thick series of sandstone and sandy shale which here represents the Montana group and the overlying formation.

Southward toward Yellowstone Valley, and beyond, the sandstones are more variable in character. Along Canyon Creek (T. 1 N., R. 23 E.), sandy shales are interbedded with ripple-marked, thin-bedded sandstones but the latter gradually become less distinct as the river is approached. The sandstones reappear southeast of Billings in lenticular beds which become quite numerous in the valley of Pryor Creek. More persistent, massive sandstones occur to the southeast, which weather cavernous and into fantastic forms similar to the Judith River, but on a less elaborate scale.

There is common throughout the entire area of the Claggett, a sandy transitional zone to the overlying Judith River formation and to the underlying Eagle sandstone, even where the sandy beds otherwise have a very subordinate development or are entirely wanting. This makes it rather difficult in many places to determine the exact limits of the formation, especially where sandstones are prominent in its upper portion. Where this happens it has been customary to include these sandstones in the Claggett, but if all traces of marine fossils are absent in them it may be advisable to call them basal Judith River.

Where the Claggett is composed of shale its topography is identical with that of the Bearpaw, broad lowlands with low rounded hills or conspicuous narrow depressions, according to the dip of the formation. In areas of horizontal beds, as on the "Billings bench," there is a high frontal escarpment of Eagle sandstone with low hills of

(65) Bowen, C. F., Anticlines in a part of the Musselshell Valley, Mont.: U. S. Geol. Survey Bull. 691-F, pp. 192-193, 1918.

PLATE VI.—EAGLE SANDSTONE.

Contact of the massive, basal Eagle sandstone (Virgelle sandstone) with the underlying Colorado shale, southwest of Billings. The Virgelle sandstone forms a common "rim-rock" overlooking valleys cut in the softer Colorado shales.

Judith River far in the background. The more massive sandstones form high cliffs, and where the formation is folded most of them give rise to more or less conspicuous strike ridges.

Complete sections may be readily observed wherever the beds are tilted and the underlying Eagle is exposed, as on the south flank of the Devil's Basin anticline, and at several points in Musselshell Valley. Excellent exposures are present along the lower Judith River and for several miles in either direction in the bluffs along the Missouri.

Measurements made in several widely separated localities indicate that the Claggett as a rule does not vary greatly in thickness. The thickest sections reported are on the east flank of the Little Rocky Mountains and on the north side of the Crazy Mountains with 750 feet and 400 to 800 feet respectively. Along Canyon Creek, northwest of Billings, it is 567 feet, near the western border of Musselshell County 467 feet, while in the Judith Basin north of Fullerton it is 620 feet thick. In the last-named locality the two-fold division is well developed,—the lower shale being about 500 feet thick and the upper sandy member 120 feet thick.

The Claggett contains a fairly abundant and varied marine fauna. Shells are found in both the shales and concretions but are more common in the latter. In a few places, as in the type area, the upper sandstones are fossiliferous. Some characteristic forms of the shale are **Baculites compressus, B. ovatus, Inoceramus barabini, Placenticeras whitfieldi,** and **Leda evansi.** The fauna is very similar to that of the Bearpaw shale but differs in that it is less diversified and fossils are less numerous.

Eagle and Virgelle sandstones.—The basal formation of the Montana group, in its fullest development, is the Eagle sandstone. This formation is of considerable interest as a possible reservoir of oil and gas. The name is derived from the section at the mouth of Eagle Creek, a northern tributary to the Missouri River in the northeastern part of Chouteau County(66.) The lower part of the Eagle has recently been called the Virgelle sandstone, from the exposures along the Missouri at Virgelle, about 25 miles below Fort Benton(67).

The Eagle sandstone has less extent than any other formation of the typical Montana group, being restricted to the western and southern portions of the plains province. North of the Missouri it appears as far east as the Little Rocky Mountains where thin encircling sandstones have been provisionally referred to the Eagle(68). In the northwestern part of the region only the massive basal sandstone, the Virgelle, can be recognized, the remainder of the Eagle, if present, having lost its identity and become a part of the Two Medicine for-

(66) Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton Folio (No. 55), p. 2, 1899.

(67) Bowen, C. F., The Stratigraphy of the Montana Group: U. S. Geol. Survey Prof. Paper 90-I, p. 97, 1915.

(68) Collier, A. J., Geology of northeastern Montana: U. S. Geol. Survey Prof. Paper 120-B, p. 26, 1918.

mation. From the type locality the Virgelle makes a broad loop to the north as the rim of the Sweetgrass arch and swings as far north as Sweetgrass on the Canadian border. Each of the three uplifts of the Sweetgrass Hills is girdled with a narrow belt of the Virgelle. From Sweetgrass it trends almost due south along the western flank of the low arch to the Sun River at the northwest corner of Cascade County, then shortly disappears beneath lava beds near Cascade. South of the Missouri, from Virgelle the Eagle outcrop is approximately parallel to the Claggett except in the few areas of the latter where erosion has not yet uncovered the underlying sandstones. The formation cannot be recognized in the Porcupine dome. On the west side of Bighorn Basin the Eagle can be traced to the Wyoming line. It is also prominently exposed in the Dean anticline and although thin is well exposed on the northeast flank of the Bighorn uplift and around the northern end of the Black Hills uplift.

The Eagle sandstone is quite generally composed of three distinct divisions; a lower very massive sandstone, a middle zone of sandy shales, and an upper division of thin sandstones. The basal member retains its massive appearance with remarkable persistence over the greater part of the area occupied by the formation. It is on account of this feature and the ready identification of this division that it is commonly called the Virgelle member. Even north of the Missouri where the upper portion of the Eagle can not be identified, the Virgelle maintains its typical appearance. It varies in color from a conspicuous white in places in the Missouri River Valley to gray and light brown in other localities. The upper part of the Virgelle north of Teton River is deeply stained with iron due to the presence of thin layers of magnetite. Cross-bedding is not uncommon, and sandstone concretions of a rusty brown hue on the weathered surface are fairly plentiful in some areas. Weathering locally develops large caverns, and less commonly fantastic pinnacles and other forms. In western Musselshell Valley the lower part of the Eagle consists of thin-bedded sandstones, which give place to sandy shales in the Dean anticline many miles to the south. Southeast of Pryor Creek, on the Crow Indian Reservation, the massive sandstone which is so conspicuous to the northwest rapidly grades into soft sandy shales that are difficult to trace.

A microscopic examination(69) of the Eagle sandstone in Musselshell Valley reveals quartz, feldspar, and black chert as the principal constituents. The sand grains here are of medium size, and vary form angular to rounded,—about 10 to 15 per cent only having the latter form. In some other areas this basal sandstone is coarser-grained.

The middle member, while commonly composed of sandy shales, is somewhat variable, becoming in some places mainly thin-bedded

(69) Bowen, C. F., Anticlines in the Musselshell Valley, Montana: U. S. Geol. Survey Bull. 691, p. 195, 1919.

or shaly sandstones. In the vicinity of the Missouri, and to a less extent in Lake Basin, carbonaceous shales and thin, lenticular coal seams are fairly abundant at this horizon.

The upper division of the Eagle exhibits a less constant nature than the others. Along Eagle Creek it consists of thin sandstones which partially pass into sandy shales south of Missouri River. In some parts of Musselshell Valley thick-bedded sandstones carrying an abundance of large rusty sandstone concretions predominate. The upper part of the formation in Stillwater Valley is a thick massive sandstone above which workable coal beds are locally present. Minable coal also occurs in the Eagle in the vicinity of Bridger and in the Elk Basin area(70). There are carbonaceous layers and thin coal seams in the upper member in the vicinity of the Bearpaw Mountains. A unique feature in part of Lake Basin is a thin bed of rounded black chert pebbles about an inch in diameter at the top of the formation. The long gentle dip slopes in places are reported to be covered with them. Another local characteristic of the member is the presence of andesitic material in western Musselshell Valley. The andesitic sandstones weather to a deep brown color and form ridges as the result of differential erosion.

The topography of the Eagle is very characteristic. The lower massive sandstone forms ledges and cliffs 25 to 100 feet high which are in striking contrast to the rolling surface of the underlying Colorado shale. It constitutes the prominent rim rock of basins in the latter formation. This is excellently exhibited in Yellowstone Valley just north of Billings. Picturesque canyons are developed where streams have cut through the gently dipping massive sandstones. Fine examples exist along Two Medicine River just above its mouth and along several small streams that cross the escarpment on the north side of Yellowstone Valley. Where the formation is steeply tilted differential erosion commonly produces a narrow strike valley bordered by a pair of hogback ridges.

The Eagle is commonly about 250 to 300 feet thick. It is estimated to be only 100 feet thick in the Little Rocky Mountains and to have a similar minimum thickness north of the Crazy Mountains. In the Blackfeet Reservation the Virgelle is reported to be 200 to 225 feet thick while farther south this increases to 380 feet. From its maximum development in this locality it decreases slightly into northern Fergus County then thins rapidly to the east, so that it is not exposed in the Porcupine dome.

Fossils are generally scarce or lacking in the Eagle. Leaves are present in places in the carbonaceous shales or are associated with the coals. In the Woman's Pocket anticline, northwest of Lavina, the marine shell **Cardium speciosum** is abundant near the top of the for-

(70) Washburne, C. H., Coal fields of the northeast side of the Bighorn Basin, Wyoming, and of Bridger, Montana: U. S. Geol. Survey Bull. 341, pp. 183-195, 1909.

mation. The same form is sparingly present in the Big Elk dome south of Two Dot(71). Marine fossils also occur in the formation in Carbon County where they are more abundant in the lower part(72). The Virgelle is reported to be barren in places but in others to contain a marine near-shore fauna.

Two Medicine formation.—The middle portion of the Montana group undergoes a decided change in lithologic character as the extreme northwestern part of Central Montana is approached. In the area between Sun River and the Canadian boundary, thence eastward to Milk River Valley, the Virgelle sandstone and the Bearpaw shale are the only divisions of the Montana group that persist in their typical aspect. The upper part of the Eagle, the Claggett, and Judith River here grade rapidly into a mass of light-colored clays and sandstones, mainly of continental origin, about 2000 feet thick. This deposit is called the Two Medicine formation from the typical and complete section exposed on the lower course of Two Medicine River in southeastern Glacier County(73).

The character of the formation is thus concisely described by Stebinger:

> It is composed principally of light-gray to greenish-gray clay and clay shale, so rudely bedded that it is impossible to follow a given stratum for any great distance. In places the beds of clay are variegated, red and yellow strata appearing. Thin nodular and non-persistent limestone, apparently of fresh-water origin, also occurs at irregular intervals. Probably 20 per cent of the total mass of the formation is made up of soft coarse-grained sandstone in lenticular beds which, even where 20 to 30 feet thick, cannot be traced more than 1 or 2 miles. At many localities these sandstones show the very irregular cross-bedding that is characteristic of eolian deposits. The lower 200 feet of the formation is more sandy than the remainder, probably half of this part consisting of massive sandstone in irregular beds, the thickest measuring 50 feet(74).

The formation contains carbonaceous shale at many horizons and three well-defined coal beds occur in some places. These coals are mined at several localities.

The succession of soft clays and more or less resistent sandstones provides ideal conditions for the formation of badlands, and consequently this type of topography is extensively developed along the numreous valleys of the region. Elsewhere the Two Medicine is characterized by a gently rolling surface.

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(71) Bowen, C. F., Anticlines in the Musselshell Valley, Montana: U. S. Geol. Survey Bull. 691-F, p. 194.
(72) Fisher, C. A., Southern Extension of the Kootenai and Montana Coal-bearing formations in northern Montana: Econ. Geol., vol. 3, p. 94, 1908.
(73) Stebinger, Eugene, The Montana group of northwestern Montana: U. S. Geol. Survey Prof. Paper 90-G, p. 62, 1914.
(74) Ibid., p. 63.

The fossiliferous character of the formation is well shown by the following description:

> Fossils are abundant in the Two Medicine formation and include vertebrate, plant, and mollusk remains of many species. Bone fragments of dinosaurs of Judith River types, both herbiverous and carniverous, and also of turtles can be found in almost any extensive exposure. Entire limb bones 4 to 5 feet in length belonging to the larger dinosaurs were found at several localities. The mollusks are represented mostly by brackish and fresh-water forms, especially the latter. Beds made up almost exclusively of unios are present at many horizons, in some places closely associated with dinosaur bones. A single marine invasion of brief duration while this formation was being deposited is represented by shells of the Claggett to Fox Hills near-shore fauna found in sandstone about 200 feet above the base of the formation. The plant remains are mainly leaf impressions and silicified wood. The leaves are all of modern-appearing conifer and broad-leaved types. The fossil wood is distributed throughout the formation, knots and entire sections of compressed tree trunks being common(75).

Livingston formation.—A thick mass of tuffaceous sandstone and shale constitutes the surface formation over an extensive area northwest of the Crazy Mountains, between Shields River and the Bridger Range, in Yellowstone Valley as far east as Greycliff, and for some distance south of Yellowstone River. These strata were called the Livingston formation by Weed(76), from exposures near Livingston. Stone and Calvert in their more recent studies of the Livingston throughout its entire area have determined its main lithologic features and its stratigraphic relations(77). They have shown too that the formation does not cover as broad a tract in the vicinity of the Crazy Mountains as is shown on the early maps of the region. The data for the following description are taken from their report.

The striking feature of the formation is the large proportion of volcanic material that it contains. Most of the shales and sandstones contain some, and many of them a great deal of andesitic debris. In the southern part of Stillwater County 320 feet of greenish to brownish tuffaceous beds intervene between the Eagle and the Lance. The formation is well-exposed along Stillwater River where a three-fold division is recognized: shale and sandstone 625 feet thick, volcanic agglomerate 2000 feet thick, and shale and thin sandstones 2500 feet thick(78). These members have a similar thickness on Boulder River

(75) Stebinger, Eugene, Geology and coal resources of Northern Teton County, Montana: U. S. Geol. Survey Bull. 621-K, p. 127, 1916.

(76) Weed, W. H., The Laramie and the overlying Livingston formation of Montana: U. S. Geol. Survey Bull. 105, p. 21, 1893.

(77) Stone, R. W., and Calvert, W. R., Stratigraphic relations of the Livingston formation of Montana: Econ. Geol., vol. 5, pp. 551-557, 652-669, 741-764, 1910.

(78) Calvert, W. R., Geology of the upper Stillwater Basin, Stillwater and Carbon counties, Montana: U. S. Geol. Survey Bull. 641-G, p. 201, 1916.

to the west. The agglomerate is composed chiefly of andesitic pebbles and boulders, which rarely show signs of transportation by water. It occurs in the form of a great lense that extends westward from West Rosebud Creek on the east to Yellowstone River, near Springdale.

On the west side of Shields Valley and along the east flank of the Bridger Range the Livingston maintains its highly andesitic nature, the only conspicuous change being the disappearance of the agglomerate member. At some places, however, strata containing much andesitic material are interbedded with the underlying Eagle and the upper part of the Colorado. A number of species of marine fossils of probable Bearpaw age were discovered well up in the typical Livingston at one locality and elsewhere Judith River forms occur at lower horizons.

As the Livingston formation is traced around the north flank of the Crazy Mountains it is observed to become less and less andesitic at certain horizons, and to assume gradually the lithologic and faunal characteristics of the Montana group. In other words, in the upper Musselshell Valley there is a gradual and apparently unmistakable interfingering of the typical sedimentary series of the central part of the state with the typical Livingston formation of the Shields and Yellowstone valleys. Hence, it is concluded that the Livingstone formation is a peculiar lithologic unit which in its particular area corresponds to the Montana group plus a part of the overlying Lance formation. Whether it may be subdivided into these formations or their time equivalents remains to be determined by detailed stratigraphic work.

Colorado formation.—Immediately underlying the Eagle sandstone, or the Claggett shale where the Eagle is absent, is a thick body of shales with subordinate sandstones known as the Colorado formation. This formation not only appears at the surface over a vast area in Montana, but underlies all the territory occupied by younger formations. Moreover, it underlies thousands of square miles of the Great Plains of the United States and Canada. The name was first applied, with its present significance, to extensive exposures in northwestern Colorado(79). In consequence of its highly petroliferous nature in Wyoming and Alberta the Colorado is of considerable interest to the oil prospector in this state.

The Colorado shale is one of the most widespread formations of the Montana Great Plains, as it is exposed over approximately 9000 square miles, or nearly one-tenth of the whole plains province. The largest area occurs north of Great Falls where it is exposed by the erosion of the Sweetgrass arch throughout an area of 7000 square miles. It is brought to the surface in belts of variable width around each of the mountain uplifts as well as in most of the anticlines and

(79) White, C. A., Report on the geology of northwestern Colorado: U. S. Geol. and Geog. Survey Terr., Tenth Annual Report, 1878.

domes of Musselshell Valley. It is also exposed in the Porcupine dome and in the northern extension of the Black Hills uplift.

The Colorado group of northwestern Wyoming has been subdivided into several formations: the Thermopolis shale at the base, the Mowry shale, the Frontier formation, the Carlile shale, and the Niobrara shale. These divisions have been identified in Elk Basin at the Montana boundary and similar divisions are recorded in the Black Hills uplift but, with the exception of the Mowry, have not been positively recognized further north. Owing to its peculiar nature the Mowry has been identified in many of the Colorado sections in Montana. It is rather probable that detailed stratigraphic study of the Colorado formation in this state will result in the recognition of some of the other divisions into which it is separated in Wyoming. On the other hand it is entirely probable that conditions of sedimentation were sufficiently diverse over such an extensive province that few, if any, horizons can be directly correlated over long distances unless they are marked by some unusual and persistent feature, as in the case of the Mowry shale. Since the Colorado sandstones exhibit great variation in number and character in the Wyoming fields, it is clearly inadvisable to consider sandstones in a particular section in this state to be the same as those that occur in some other section 50 to 100 miles distant, and thus expect them to exhibit the same features.

The Colorado everywhere is dominantly a dark bluish-gray to black, more or less fissile, clay shale. It contains variable amounts of sandy shales and sandstones, the latter as a rule being more numerous and thicker in the lower part of the formation. This is especially true in Bighorn Basin, Wyoming, but even here they are very lenticular. The sandstones appear to become less abundant and to be more limited in vertical range as the state is crossed toward the north. In the Elk Basin field the principal horizons are the Peay and Torchlight members of the Frontier formation, both of which are oil-bearing, while in the Bridger section the Torchlight is the only important sandstone(80). Well logs at Billings, southwest of Broadview, and southeast of Shawmut show several thin sandstones in the lower third of the Colorado section. In the western part of Musselshell Valley sandstones again become numerous and thicker, one sandy horizon in the Big Elk dome being sufficiently prominent to warrant the name Big Elk Sandstone(81). This member is about 1200 feet below the top of the formation, and is about 250 feet thick. It occupies the approximate position of the Frontier of Wyoming. Near the Crazy Mountains about 200 feet of sandstones are present in the lower third of the Colorado. The basal sandstones in the vicinity of the Big Snowy Mountains are thick-bedded and weather to

(80) Hares, C. J., unpublished data, quoted by Hancock, E. T., U. S. Geol. Survey Bull. 711, Plate XV, 1920.

(81) Bowen, C. F., Anticlines in a part of the Musselshell Valley, Montana: U. S. Geol. Survey Bull. 691-F, p. 196, 1918.

a rusty brown color. These "rusty beds" are an excellent guide in drawing the lower boundary of the formation in this area.

Sandstones, many of which are 20 to 80 feet thick, are prevalent in the lower half of this formation in the northern part of the state. A section on the flanks of the Little Rocky Mountains that may be considered representative for the northeastern area consists of 100 feet of Mowry shale at the base, 325 feet of dark-blue shale, 60 feet of sandstone capped by a thin bed of fossiliferous limestone, and 875 feet of bluish-gray to black shale with numerous limestone concretions(82).

In the northwestern part of the plains the lower third of the Colorado has been designated the Blackleaf sandy member from the good exposure on Blackleaf Creek, in northern Teton County. A detailed section of it is given by Stebinger in U. S. Geological Survey Bull. 691-E, page 158. This division is 600 to 700 feet thick and contains all the conspicuous sandy horizons of the Colorado in this region. The sandstones are medium to coarse-grained, locally conglomeratic, and are somewhat lenticular. Numerous marine and brackish-water shells have been found in the sandy shales associated with them.

The beds immediately overlying the Blackleaf in the Sun River district are distinctly petroliferous. They "consist of compact black bituminous shale containing thin beds of impure limestone which in places is impregnated along the fractures with a soft tarry bitumen(83). Upon distillation the shales yield one to two gallons of oil to the ton. These beds are about 50 feet thick, with the several thin limestones occupying about one-quarter of the space.

The Mowry shale, which, owing to the abundance of fish remains that it contains, is a possible source of oil, has been identified at several places in Montana. Where typically developed it is readily recognized by the great numbers of fish scales and its peculiar weathering to a porcelain-like debris. This member is reported from the Little Rockies as constituting the basal 100 feet of the Colorado. It is present on the northeast flank of the Bearpaw Mountains and in the vicinity of Great Falls and Lewistown, but has not been recognized in the intermediate area. It apparently occurs only in the eastern part of Musselshell Valley, forming a 12-foot stratum about 680 feet above the base of the Colorado in the Devil's Pocket anticline and is also well exposed in the Cat Creek anticline. Near Bridger the Mowry is over 200 feet thick.

The upper part of the Colorado nearly everywhere consists of characteristic dark-colored fissile shale. Thin beds of sandstone, limestone, and sandy shale are present in places but they are relatively

(82) Collier, A. J., Geology of northeastern Montana: U. S. Geol. Survey Prof. Paper 120-B, p. 26, 1918.

(83) Stebinger, Eugene, Oil and gas geology of the Birch Creek-Sun River area in northwestern Montana: U. S. Geol. Survey Bull. 691-E, p. 162, 1918.

unimportant. Calcareous concretions more or less filled with veins of calcite are rather common in this division. A bed of volcanic ash is a local feature on the south side of the Highwood Mountains, and tuffaceous material occurs near the top of the formation on the north side of the Crazy Mountains.

The summit of the Colorado is generally quite distinctly marked by a change from the dark shales to the light-colored massive sandstone or sandy shale of the basal Eagle, as well as by the conspicuous difference in topographic expression. These upper Colorado shales bear a rather close resemblance to the Claggett and Bearpaw shales but differ in that they are somewhat darker, bedding is much better developed, and a typical gumbo soil is more rarely produced.

Typical sections of the formation are well exposed at several places in the state, particularly on the flanks of the mountain uplifts, as along the northwest end of the Pryor mountains. For the details of several complete sections the reader is referred to the publications of the U. S. Geological Survey(84).

The Colorado formation has a rather uniform thickness throughout the state. It is approximately 1360 feet thick in the Little Rockies and in the northwestern part it varies from 1500 to 1900 feet. It is about 1300 feet thick north of the Crazy Mountains and ranges from 1500 feet north of the Judith Mountains to 2360 feet on the south side of the Big Snowy Mountains. The greatest thickness in Musselshell Valley approximates the latter figure. A section in the Elk Basin district nearly 2700 feet thick apparently records the maximum development of the formation in Montana.

Marine fossils are plentiful in the Colorado shale. Fish remains are exceedingly numerous in the Mowry shale member, but occur also at other horizons in some localities. Shells of invertebrates, chiefly pelecypods and gastropods, are not uncommon in most extensive sections, both in the shale and in the calcareous concretions of the upper portion. All the fossils are characteristic marine Cretaceous forms.

THE COMANCHEAN SYSTEM.

Kootenai formation.—The Kootenai formation consists of a widespread series of shales and sandstones that underlies the Colorado shale. The type locality is in southwestern Alberta, whence the name is derived from an Indian tribe that frequented the region(85). The formation passes beneath the surface before the international boundary is reached but reappears at several places in the plains province. North of Missouri River it crops out only in the Little Rocky Moun-

(84) Bowen, C. F., Anticlines in a part of the Musselshell Valley: Bull. 691-F, pp. 196-197, 1918; Calvert, W. R., Geology of the Lewistown coal field, Bull. 390, p. 30, 1909; Hancock, E. T., Bull. 691-D, Pl. XVII or Bull. 711-G, Pl. XV, 1920.

(85) Dawson, Sir William, On the Mesozoic floras of the Rocky Mountain region of Canada: Trans. Royal Soc. Canada, vol. 3, Sec. 4, p. 2, 1885.

tains and along the Rocky Mountain front. The greatest surface exposure in the state is east and southeast of Great Falls where it occupies about 400 square miles. A much smaller area exists southeast of Lewistown, and a belt of the formation encircles each of the mountain uplifts in this part of the state. The only other outcrops in the plains is a narrow belt around the northern extremities of the Bighorn and Pryor mountains and small areas in the Devil's Basin and Cat Creek anticlines. That is underlies the younger formations, at least in the central part of the plains province, is shown by its having been penetrated by deep wells.

The Kootenai formation consists essentially of alternating, varicolored shales and light-colored sandstones. The sandstones are numerous and thick in the lower half and, as a rule, become thin and scattered in the upper portion although in many places there is a massive, coarse sandstone in the upper third of the formation, in which occurs the second and third sands of the Mosby oil field. It may correspond to the Greybull sandstone member of the Cloverly in Bighorn Basin. The sandstones are commonly gray to brown, medium to coarse-grained, in many places gritty to coarsely conglomeratic, and locally strongly cross-bedded. The lower ones vary in thickness from 10 to 60 or more feet, and thus afford good horizons for oil accumulation if other conditions are favorable. Some of the sandstones are rather nonpersistent in the central part of the state, but one stratum less than 100 feet above the base is so persistent in the vicinity of the Big Snowy Mountains that it makes an excellent horizon marker. It is as easy to trace owing to the numerous pines which grow upon it.

Just below this sandstone occurs the workable coal seam of the Lewistown and Great Falls fields, which in places is six feet thick. In other districts this horizon is represented by a thin coal seam or by carbonaceous shale.

Limestone is sparingly present in the Kootenai and occurs generally in the form of nodules in more or less definite zones, or as thin lenticular beds. It is commonly gray to buff, but locally is purplish.

The variegated shales are the striking and distinctive feature of the Kootenai formation. It is so similar to the underlying Morrison in this respect that the two formations are readily confused, and can only be differentiated by detailed work. The Kootenai shales are dominantly clayey, but are more or less sandy in places. The distinctive color is reddish to maroon, with bands of gray, blue and green. The maroon shales are present at several levels in the formation, but the bulk of them are in the upper portion, immediately underlying the "rusty beds" that mark the base of the Colorado. These upper shales weather to soils of a deep maroon color, which can be readily distinguished at great distances. The sharp change in lithology at the upper contact is very conspicuous along the east side of the Big Snowy Mountains, but is commonly less evident elsewhere.

The two formations appear to be everywhere conformable, but the absence of the Dakota sandstone indicates the existence of a marked hiatus at this horizon.

Good sections of the Kootenai are rather scarce. A full section may be measured in several deep ravines on the north and east flanks of the Big Snowy Mountains, on the north slope of the Little Belt Mountains, and in Bridger Canyon. A section at the last locality shows the following sequence(86).

	Feet
Sandstone and shale interbedded; sandstone micaceous, in paper-thin beds, in places cross-bedded, light buff to greenish yellow, marked by great number of worm burrows or tracks; shale light colored and sandy; at the top are great numbers of small rounded balls which contain phosphatic material and are pseudomorphs after marcasite. This member is ridge-forming and contains at the bottom the Greybull sandstone member	217
Shale, brilliantly colored, containing great numbers of gastroliths and a few bones. The different colors give the shale a banded effect and are well exposed in Rainbow Butte, just north of Bridger Canyon	95
Conglomerate, composed mostly of black chert pebbles 2 inches or less in diameter containing Paleozoic fossils. Toward the top the conglomerate becomes sandy and contains fewer pebbles. The conglomerate forms cliffs on each side of Bridger Canyon	35
	257

This section is of the Cloverly formation, which is approximately equivalent to the Kootenai.

A section on the east flank of the Little Belt Mountains illustrates the common features of the formation in the central part of the state(87).

Colorado Shale.	Feet
Shale, maroon, sandy, with an occasional thin sandstone layer	200
Sandstone, gray, weathering tan, coarse grained	8
Shale, maroon, sandy	60
Sandstone, gray, coarse grained, weathering irregularly and containing woody fragments	25
Shale, maroon, sandy	72
Sandstone, gray, massive, pebbly	50
Partly concealed; sandstone members in upper part	42
Shale, grayish brown, compact	6
Coal and carbonaceous shale	3
Concealed, probably greenish, sandy shale	87
Morrison formation.	
	553

(86) Measured by C. J. Hares; quoted by E. T. Hancock, U. S. Geol. Survey Bull. 691-D, p. 110, 1918.

(87) Calvert, W. R., Geology of the Lewistown coal field, Montana: U. S. Geol. Survey Bull. 390, p. 26, 1909.

The Kootenai is about 500 feet thick in Fergus and Cascade counties, but increases to 825 feet in the Little Rocky Mountains and to approximately 2000 feet in the northwestern part of Central Montana. It becomes even thicker in western Alberta, where it attains a thickness of 2800 feet. It thins to the west and south, being about 235 feet thick north of the Crazy Mountains and 257 feet thick in Bridger Canyon. Farther south in the Bighorn Basin the Cloverly is only slightly more than 100 feet thick.

Fossils as a rule are scarce in the Kootenai, and present little diversity. The most common ones are leaves in the carbonaceous strata, which are abundant in the Great Falls district. A few fresh-water shells, mainly Unios and Gastropods, occur in some places. Reptilian bones have also been discovered. All the fossils indicate the terrestrial origin of the formation.

Morrison formation.—The Morrison formation is a widespread sheet of fresh-water deposits that extends from far south of Morrison, Colorado, the type locality(88), as far north at least, as Central Montana. Wherever present it underlies the Kootenai, to which it bears such a close resemblance that it is difficult to separate the two formations in most places. It has been identified only along the north slopes of the Little Belt, Big Snowy, Bighorn and Pryor mountains in this state, but probably is buried by younger formations in the intervening and adjacent territory.

The following description of the formation along the north flank of the Big Snowy Mountains will apply throughout the state(89):

> The Morrison formation consists of shales, sandstones, and argillaceous limestones, all apparently of fresh-water origin. The colors of these beds are extremely variable, greens and pinks predominating, but they are seldom, if ever, brilliant and possess a characteristic soft tint. In lithologic character and in thickness the formation is fairly uniform throughout the field, the various sections approximating 125 feet. Argillaceous members predominate. The shales are very clayey and the limestones also appear to contain a high percentage of silica. The limestone members are characteristically bluish gray and break into small blocks. The sandstones are usually brownish and granular in appearance, and in them comminuted bone fragments are of fairly common occurrence.

Good sections of the Morrison are available wherever sharp valleys have been cut into the underlying formation. The following section illustrates in detail its character near the east end of the Little Belt Range(90):

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(88) Cross, Whitman, U. S. Geol. Survey Geol. Atlas, Pike's Peak folio (No. 7), 1894.

(89) Calvert, W. R., Geology of the Lewistown coal field, Montana: U. S. Geol. Survey Bull. 390, pp. 22-23, 1909.

(90) Ibid., p. 23.

	Kootenai Formation.	Feet
1.	Sandstone, fine grained, tan-colored, weathering soft tan, containing bone fragments	12
2.	Shale, greenish, becoming sandy upward, with 1-foot layer of limestone, greenish gray, weathering russet 12 feet from top; shale contains many Unio shells	34
3.	Limestone, reddish brown, weathering russet, containing an abundance of clear calcite crystals	3
4.	Shale, greenish	8
5.	Limestone and variegated shale; limestone is in thin layers, reddish brown, unchanged by weathering, with calcite crystals as in (3)	11
6.	Limestone, fine grained, compact, containing small greenish particles resembling glauconite	2
7.	Shale, variegated, red and pink, predominating	75
	Ellis sandstone.	
		145

Another complete section southeast of Bridger shows the nature of the formation in the southern part of the state(91):

	Feet
Shale, light colored	13
Shale, reddish brown and maroon	7
Shale, light sandy	16
Sandstone, light colored, fine to medium grained; weathers yellowish. In places massive and locally in beds from 1 foot to 1½ feet thick	26
Shale, variegated, commonly light colored. Has a thin maroon streak near the base and a dark-gray streak near the top	26
Sandstone, single bed, very argillaceous	½
Shale, dark to reddish brown; weathers reddish; exhibits 1 foot of light shale near the top	10
Sandstone, light colored	5
Shale, variegated from light to reddish brown	13
Sandstone, light colored	13
Shale, maroon; contains some interbedded sandstone; weathers light to yellowish brown	10
Shale, dark; weathers light. Greenish, light brown and drab are common shades	10
	149½

The Morrison is a comparatively thin formation in this state, ranging from 60 to 120 feet in southern Cascade County to 150 feet in Elk Basin. It thickens to the south, and is nearly 600 feet thick along Shoshone River in northern Wyoming.

Fossils are very abundant in the formation in many places but only a few have been collected from the outcrops in this state. They consist of plant remains, invertebrates, and bones of several vertebrates, all of which denote its terrestrial origin. None of them,

(91) Emery, W. B., quoted by E. T. Hancock, U. S. Geol. Survey Bull. 711-G, p. 112, 1920.

however, afford conclusive evidence of its precise position in the stratigraphic column, some geologists calling it Comanchean(92), whereas others consider it as Jurassic(93). It seems quite probable that it is largely transitional but is closely allied to the Kootenai.

THE JURASSIC SYSTEM.

Ellis formation.—The Ellis formation is the basal Mesozoic formation throughout the greater part of the plains province. Except in a small area in southern Carbon and Bighorn counties, where the Chugwater formation (Triassic) is present, it rests everywhere upon sediments of late Paleozoic age. In places it overlies the Madison limestone and the Quadrant formation with marked angular conformity, for example, in the vicinity of Stockett, southeast of Great Falls(94). Even where no unconformity is apparent the absence of strata that normally intervene between the Madison and the Ellis indicates a pronounced gap, or hiatus, in the sedimentary record.

The areal distribution of the Ellis is similar to that of the Morrison and Kootenai except that its outcrop is more restricted than that of the latter. It occurs in narrow belts on the flanks of the several mountain uplifts and as long narrow embayments that extend far down some of the narrow valleys on these slopes. The formation is exposed along the western margin of the plains in Teton County, and surrounds the Judith, Big Snowy and Little Belt mountains. On some of these slopes the outcrop varies in width from a small fraction of a mile to several miles. The Ellis forms the central area of several small domes in the vicinity of Lewistown. It is present on the flanks of the Bighorn and Pryor mountains where it passes into the Sundance formation of Wyoming. North of Missouri River it appears at the surface in the Little Rocky and Bearpaw mountains and in the Sweetgrass Hills. Its subsurface distribution is unknown but it probably is present under the greater part of the plains in this state.

The formation is composed of sandstone, shale, and limestone in variable proportion. The following section illustrates its character in the Little Rocky Mountains(95):

	Feet
Sandstone, massive, white, cross-bedded	50
Shale, variegated	50
Sandstone, yellowish and thinner bedded	100
Shale with interbedded sandstone and limestone	100
Limestone, thin bedded, shaly and calcareous shale	200
	500

(92) Mook, C. C., A study of the Morrison formation: Annals N. Y. Acad. Sci., vol. 27, pp. 39-191, 1916.
(93) Schuchert, Charles, Bull. Geol. Soc. Am., vol. 29, p. 246, 1918.
(94) See U. S. Geol. Survey Bull. 356, Pls. I and VI, 1909.
(95) Collier, A. J., Geology of northeastern Montana: U. S. Geol. Survey Prof. Paper 120-B, p. 25, 1918.

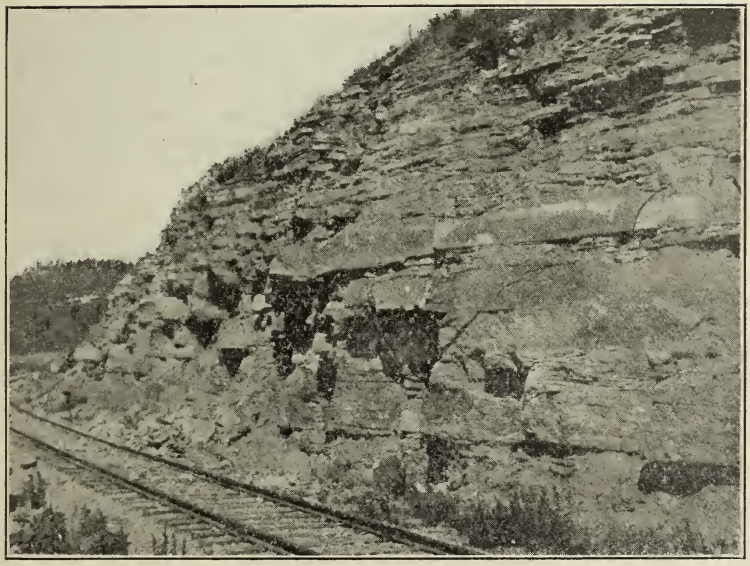

PLATE VII.—ELLIS FORMATION.

Fossiliferous limestones exposed in a railroad cut 3 miles west of Forest Grove. The thicker beds are overlain by thin-bedded calcerous shales.

In the Bearpaw Mountains it consists of a fine-grained, dark gray, highly fossiliferous limestone about 200 feet thick(96).

A section south of Great Falls in T. 17 N., R. 4 E. shows the common features for this region(97):

	Feet
Sandstone, gray, weathering brown, thin bedded	60
Sandstone, gray, conglomeratic, containing marine Jurassic fossils	29
Limestone, dove colored, massive; basal member brecciated and containing Jurassic fossils	60
	149

In western Teton County the formation is composed mainly of dark calcareous shales with a few thin irregular beds of sandstone and limestone, ranging in thickness from 240 to 310 feet(98). In the Lewistown district the Ellis consists of thick, coarse-grained to conglomerate sandstones which alternate with thin limestones and red and green shales. The sandstones form prominent tan-colored cliffs or ridges wherever well exposed. Some of the strata contain considerable gypsum. The formation ranges in thickness here from 65 feet on the northeast slope of the Little Belt Mountains to 440 feet in the South Moccasin Mountains.

Similar features characterize the Sundance formation along the northeast flank of the Bighorn Range, as is shown by this typical section(99):

	Feet.
Green to brown fossiliferous sandstones	3
Green sandy shale	20
Alternating layers of green and gray sandstones, fossiliferous at top	25
Gray sandy shale; red at base; concealed above, probably green	115
Light-gray limestone; oolite at base; thin-bedded above; fossiliferous	15
Gray massive fossiliferous sandstones	6
Thin-bedded limestone	12
Gray sandy shale	60
Massive gray sandstone; very fossiliferous	10
	266

The Ellis formation is nearly everywhere rich in fossils at several horizons, some beds being almost wholly composed of shells and shell fragments. This feature is especially exhibited in a cut along the Milwaukee Railway about 15 miles east of Lewistown. The forms are all marine or brackish-water invertebrates, among which

(96) Bowen, C. F., The Cleveland coal field, Blaine County, Montana: U. S. Geol. Survey Bull. 381, pp. 51-52, 1909.

(97) Fisher, C. A., Geology of the Great Falls coal field, Montana: U. S. Geol. Survey Bull. 356, p. 28, 1909.

(98) Stebinger, Eugene, Oil and gas geology of the Birch Creek-Sun River area, northwestern Montana: U. S. Geol. Survey Bull. 691-E, p. 155, 1918.

(99) Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, p. 45, 1906.

Belemnites densus, a cigar-shaped shell, and **Gryphaea calcaola,** an oyster-like form, are most characteristic. All the fossils indicate the late Jurassic age of the Ellis. It is thus stratigraphically and faunally the same as the Sundance formation of the Bighorn Mountains.

THE TRIASSIC SYSTEM

Chugwater formation.—The only rocks of Triassic age in the plains province of Montana are contained in the Chugwater formation, which extends northward from extensive exposures in Wyoming as a narrow belt around the northern extremities of the Bighorn and Pryor mountains. The name was first applied to the section on Chugwater Creek, near Iron Mountain, Wyoming(100). The formation is well exposed in Bridger Canyon, southeast of Bridger, just south of the Billings-Cody highway, where it forms the core of a small anticline. It crops out far down the long dip slope of Paleozoics at many other places in both mountain ranges. Typical features are likewise exhibited a few miles south of Pryor, on the Crow Indian Reservation, and in the eastern half of T. 6 S., R. 24 E. The formation also crosses the state line along the east base of the Beartooth Range; elsewhere it is not present in Montana.

The Chugwater is aptly called the "Red Beds," as it consists mainly of bright to dark red sandstones and sandy to clayey shales. These brilliantly colored strata form conspicuous cliffs and ledges wherever exposed and thus are an excellent horizon marker. A fine example of this is the "red wall" in Bridger Canyon. Several beds of massive gypsum from 6 to 50 feet thick are present in places. A few thin limestones are interbedded with the sandstones and shales.

A section in the eastern part of the Crow Reservation gives a thickness of 652 feet for the formation. It becomes thicker south of the state line, and reaches a maximum of 1200 feet.

Fossils are very rare in the Chugwater and thus its age is rather uncertain. Recent stratigraphic studies in the eastern part of Bighorn Basin have led to the conclusion that the true Chugwater is probably of Triassic age(101).

CORRELATION OF THE MESOZOIC

The succession and equivalency of the Mesozoic formations in various parts of the Montana plains are shown by the correlation chart on page 66. The overlying Lance and the underlying Quadrant and Madison formations are also included. Sections north of the

(100) Darton, N. H., Comparison of the stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range: Bull. Geol. Soc. Am., vol. 15, p. 397, 1904.

(101) Condit, D. D., Relation of the Embar and Chugwater formations in central Wyoming: U. S. Geol. Survey Prof. Paper 98, pp. 263-270, 1916.

Correlation of the Mesozoic and Late Paleozoic formations of the plains province of Montana and adjacent states.

System	Southern Alberta	Northwest Montana	West-Cen. Montana	Elk Basin	East-Cen. Montana	Black Hills
Cretaceous	St. Mary River f.	St. Mary River f.	Lance form. (Livingston form.)	Lance formation	Lance formation	
	"Fox Hills" ss.	Montana Group: Horsethief ss.	Lennep ss.		Fox Hills ss. (?)	Fox Hills ss.
	Pierre shale	Bearpaw shale	Bearpaw shale	Bearpaw shale	Bearpaw shale	Pierre shale
	Belly River formation	Two Medicine formation	Judith River f.	Judith River fm.	Judth R.	
			Claggett sh.	Claggett shale	Claggett shale	
		Virgelle ss.	Eagle sandstone	Eagle sandstone	Eagle	
	Lower dark shales	Colorado formation; Blackleaf Sandy member	Colorado formation	Colorado Group: Niobrara sh.	Colorado formaton	Colorado Group: Niobrara
				Carlile sh.		Benton: Carlisle sh.
				Frontier form.		
				Mowry sh.		Greenhorn Ls.
				Thermopolis sh.		Greenhorn Ls.
	?	(Absent)	(Absent)	(Absent)	?	Dakota ss.
Comanchean	Kootenai form.	Kootenai form.	Kootenai form.	Cloverly form.	Kootenai (n wells)	Fuson shale; Lakota ss.
..... ?	Fernie shale	?	Morrison form.	Morrison form.	Morrison (in wells)	Morrison form.
Jurassic		Ellis formation	Ellis formation	Sundance form.	Ellis (in wells)	Sundance form.
Triassic	?	(Absent)	(Absent)	Chugwater form.	(Absent)	Spearfish form. Minnekahta Ls. Opeche form.
..... ?						
Permian		(Absent)	Quadrant formation	Embar form.	Quadrant formation (in wells)	
Pennsylvanian	?			Tensleep ss.		Minnelusa formation
				Amsden form.		
Mississippian		Madison Ls.	Madison Ls.	Madison Ls.		Pahasapa Ls.

Canadian boundary, in northwestern Wyoming, and in the northwestern part of the Black Hills are given for a comparison in order to show the relation of the formations in Montana to those in neighboring states.

The section in Alberta is taken along the western margin of the Great Plains, in the southern part of the province, and is based upon work by the Canadian Geological Survey. Several publications of the United States Geological Survey supply the data for the sections in Montana. The Elk Basin section shows the formations for several miles on both sides of the Montana-Wyoming boundary. The formations below the Colorado are exposed along the southwest slope of the Pryor Mountains and the east base of the Beartooth Range. The section in the Black Hills is taken from the Aladdin folio (No. 128) and exhibits the formations that are present in southeastern Montana.

THE PALEOZOIC

Formations of Paleozoic age crop out in the plains province only where mountain-making forces have greatly unwarped the strata and erosion has deeply dissected the uplifts. Good sections are exposed in several of the Rocky Mountain front ranges and the Little Belt and Judith Mountains. The later Paleozoics also occupy the greater part of the Bighorn, Pryor, and Big Snowy mountains, and a small area in each of the Sweetgrass Hills.

The only formations in this group of immediate interest to the oil prospector are those of Carboniferous age, mainly the Quadrant formation, as the older formations are not oil-bearing in the Great Plains nor Rocky Mountains. In many of the anticlines the Quadrant is too deeply buried to be economically accessible, but where reached by the drill it offers some encouragement for further exploration. The lithology of some of the older formations, however, is of pertinent interest in its possible bearing upon the source of the oil and gas that occur in younger formations.

THE CARBONIFEROUS SYSTEM

Quadrant formation.—The Quadrant formation, which receives its name from the section in Quadrant Mountain in Yellowstone Park(102), is the youngest Paleozoic formation in this province. It crops out extensively between the prominent Madison limestone and the Ellis formation in several mountain uplifts, but is absent in some localities. It is probably concealed over a broad area, but little is known of its distribution beneath the surface of the plains. The best exposures of the Quadrant formation occur on the lower slopes of the Little Belt and Big Snowy mountains, in the southern part of the Judith Mountains, and to a less extent in the Little Rocky Moun-

(102) Peale, A. C., U. S. Geol. Survey Bull. 110, pp. 39-43, 1893.

tains. The formation is also present in the various front ranges of the Rocky Mountains. The Amsden and Tensleep formations, which are approximately equivalent to the Quadrant formation, occupy a similar position in the Bighorn and Pryor mountains.

As described by Weed the Quadrant in the Little Belt Mountains consists of basal reddish sandy clays and sandstone with some gypsum in a few places, overlain by several hundred feet of bright green and gray shale with interbedded gray limestones(103). In this area the formation is commonly between 300 and 400 feet thick, but it is reported to be 1400 feet thick on Judith River above Utica.

The following section shows the character of the formation at the east end of the range(104):

		Feet
	Jurassic; red shale.	
1.	Limestone, light gray, weathering almost white, fossiliferous in upper portion	55
2.	Shale, green, alternating with limestone members near top; beds partly concealed	105
3.	Sandstone, white, soft, saccharoidal, basal members alternating with limestone layers, all weathering like limestone	40
4.	Shale, red, containing an abundance of irregular cherts; beds partly concealed	225
	Madison limestone.	
		425

The Quadrant in this area contains many fossils in its upper strata, all of which are marine invertebrate shells of either late Mississippian or early Pennsylvanian age.

Madison limestone.—The Madison limestone wherever well exposed is one of the most conspicuous formations of the region. Like the Quadrant it is exposed only in the mountain ranges, being present in each of the uplifts of the plains province as well as in the front ranges of the Rocky Mountains.

It consists of 1000 to 1500 or more feet of gray to bluish-gray, thin-bedded to very massive, fine-grained limestone which contains more or less chert and numerous fossils. In some areas the basal portion is composed of shales and shaley limestone. The massive members everywhere give rise to a rugged topography,—narrow box canyons and high steep cliffs and walls being common. In some of the uplifts, as in the Little Rocky Mountains, it forms a striking encircling girdle broken here and there by picturesque canyons.

The diversified marine invertebrate fauna of the Madison indicates its Mississippian age.

(103) Weed, W. H., Geology of the Little Belt Mountains, Montana: U. S. Geol. Survey, Twentieth Ann. Rept., pt. 3, pp. 294-296, 1899.

(104) Calvert, W. R., Geology of the Lewistown coal field, Montana: U. S. Geol. Survey Bull. 390, p. 16, 1909.

OLDER FORMATIONS

Beneath the Madison limestone there is a thick series of alternating shales and limestones with few interbedded sandstones which comprises the Devonian and Cambrian systems. Rocks of Silurian and Ordovician age apparently are absent except in the Bighorn and Pryor mountains where strata of the latter age are present. These earlier Paleozoic formations are well-exposed in the mountain ranges in the vicinity of Lewistown. Only the Devonian formations, the Jefferson limestone and the overlying Three Forks shale, are of interest in this report. In the central part of the state they consist of a few hundred feet of alternating limestones and shales, which are commonly light- to dark-gray, brown, or black and emit a strongly fetid odor when freshly broken. Both the color and odor are due to considerable finely disseminated organic matter. Fossils, however, are rarely present. Some of the beds are more or less sandy, and a few sandstones as well as most of the limestones have a distinct saccharoidal or granular texture.

Whether these beds are the source of some of the oil and gas of the plains province is unknown, but such an origin is not improbable. If this be the case, the sub-surface distribution of these formations is of great importance, but at present this is almost wholly conjectural. Since Devonian formations are exposed in all the mountain ranges, it seems fairly certain that they underlie the intermediate areas and much of the adjacent territory. Thus they probably extend far eastward beneath the younger formation of the plains, but their eastern limit is unknown.

PART III

ECONOMIC GEOLOGY

BY

G. S. LAMBERT

COAL

Although this bulletin is particularly concerned with the oil and gas possibilities of Central and Eastern Montana, the value of the coal resources of the area justifies a short description of the coal deposits. Coal is known to occur in the Kootenai, Eagle, Two Medicine, Judith River, Lance, and Fort Union formations, ranging in age, therefore, from the Lower Cretaceous, or Comanchean, to the Tertiary. In quality it ranges from brown, woody-fibered lignites in Eastern Montana to sub-bituminous and bituminous coals nearer the mountain front.

Kootenai coal.—Kootenai (Comanchean) coal is found at a horizon about 60 feet above the base of the formation in the Great Falls and Lewistown areas, the former being the more important. The seam is from 3 to 12 feet in thickness, is characteristically irregular, and consists of alternating coal, clay, and bone ash beds(105). It is a medium grade bituminous coal but its value, especially in the Lewistown area, is greatly diminished by the inclusion of a large amount of slate.

Eagle coal.—Eagle (Cretaceous) coal is mined in the Bridger and adjacent fields, and in the Livingston, Trail Creek, Electric, and Stillwater Valley fields, all of which are located in the southwest-central part of Montana. In northern and eastern Montana, the Eagle formation is relatively barren, although small seams of coal are reported north of Black Butte in the vicinity of Deerfield, Fergus County(106). The Eagle coal, which is found in the sandy beds overlying the massive Virgelle sandstone member, is bituminous, but the seams are variable in thickness and most of them high in ash. Only

(105) Fisher, C. A., Geology of the Great Falls coal field: U. S. Geol. Survey Bull. No. 356, pp. 50-51, 1909.

(106) Bowen, C. F., Coal between Musselshell and Judith, Montana: U. S. Geol. Survey Bull. No. 541-H, p. 45, 1912.

that coal which has been crushed during deformation and converted into a coking coal, can be profitably mined.

Two Medicine coal.—Two Medicine (Cretaceous) coal, correlated with the Belly River coal of Canada, is mapped only in the northwest central part of the state, around the Sweetgrass Hills. It occurs at three horizons, at the base, 250 feet above the base, and at the top of the formation. Elsewhere there is coaly matter in carbonaceous shales 2 to 5 feet thick(107). There is but little production of Two Medicine coal but it is medium grade bituminous and does not weather materially and hence is a fair fuel when mined clean.

Judith River coal.—The productive coal areas of the Judith River (Cretaceous) formation, the equivalent of part of the Two Medicine formation, are the Milk River, Cleveland, Big Sandy, and Judith Basin fields, the first two being by far the most important. The most extensive mining is at Havre in the Milk River field. The Milk River and Cleveland fields are situated, respectively, along Milk River, north of the Bearpaw Mountains, and at the east end of the Bearpaw Mountains. The Big Sandy field is situated at the southwest end of the Bearpaw Mountains and the Judith Basin field lies about 30-35 miles farther south. The coal occurs between 15-150 feet below the top of the formation in lenticular seams which vary in thickness from a fraction of an inch to 9 feet(108). The coal is sub-bituminous and contains a large amount of impurities. It has a low heat value, high moisture and high volatile content, and disintegrates rapidly, hence is a poor railroad or shipping coal, but is a valuable producer gas coal.

Lance coal.—There is no coal being mined from the Lance formation, as mapped by this survey, except for local household use, as the formation contains only thin, unimportant lignite seams and carbonaceous material.

Fort Union coal.—The Fort Union (Tertiary) coal fields include the well known Red Lodge-Bear Creek and Bull Mountain (Roundup) coal fields, as well as the extensive lignite fields of Eastern Montana. These fields, if considered as bounded by the Lance-Fort Union contact as shown on the accompanying geologic map, total about 30,000 square miles in area.

The Fort Union formation consists of alternating sandstones and shales with numerous lignite and sub-bituminous coal seams. It has, however, been determined by the U. S. Geological Survey that only those seams which are 30-36 inches in thickness can be profitably mined. Whereas, a great many seams do not attain this thickness, at

(107) Stebinger, Eugene, Geology and coal resources of northern Teton County, Montana: U. S. Geol. Survey Bull. No. 621-K, p. 126, 1915.
(108) Pepperberg, L. S., Milk River coal field, Montana: U. S. Geol. Survey Bull. No. 381-A, pp. 82-83, 1908.

least 10-15 seams do. It is reported that in the Sidney Lignite field, situated in the extreme eastern part of the state, 980 feet of Fort Union strata contains 49 feet of lignite in seams varying in thickness from 1 inch to 21 feet. The ratio of coal to the entire measures is, therefore, 1 : 20, whereas, the ratio in the Appalachian fields is about 1 : 40(109). Eleven of the lignite seams are considered economically important.

In the Bull Mountain field in Central Montana are 26 coal seams, all of which are more than 1 foot in thickness. In contrast with the typical woody-textured lignites of the more easterly Fort Union fields, the coal of the Bull Mountain and Red Lodge-Bear Creek coal fields is sub-bituminous. This is undoubtedly due to the metamorphism of the lignites during deformation of the Fort Union rocks of Central Montana. This coal may be shipped without significant deterioration and is good steaming coal, hence it has become important both as domestic fuel and for use by the railroads. The mines in the Bull Mountain and Red Lodge-Bear Creek fields are now the principal coal producers of Montana, producing over 63% of all the coal mined in the state. The production in the two districts during 1918 was 2,810,196 tons(110), and from information available at this time, it appears that the 1919 production was equal to that of 1918(111).

The utilization of the vast reserves of lignite in the more eastern fields constitutes one of Montana's most interesting problems. Among the economic possibilities are these: Briquetting of the lignite to furnish domestic fuel, burning of the lignite at the place of production to generate electric power, and distilling of the lignite into various commercial products such as producer gas and coal tars. Commercial products resulting from the distillation of coal are of increasing importance and although heretofore they have been derived almost entirely from the by-products of coking plants, it is not improbable that, in the near future, they will be obtained from lignite such as is found in Montana. Among the more important products secured are creosote oil, light oils, benzols, solvent naphthas, and heavy tars and pitch products. These furnish dye stuffs, various chemicals and drugs, tars and pitches used in many industries, motor fuels, and raw materials used in the manufacture of explosives.

OIL AND GAS

Development

The search for oil and gas in Montana began in 1897 when four shallow wells were drilled in Carbon County, (Section 32, T. 6 S., R. 18 E). The next year a well was drilled in Blaine County, near

(109) Stebinger, Eugene, Sidney lignite field, Montana: U. S. Geol. Survey Bull. No. 471-D, p. 287, 1912.
(110) Mineral Resources of the U. S., 1918, Part II, p. 769.
(111) Mineral Resources of the U. S., 1919, Advance coal data.

Chinook. In 1901 wells were drilled in Flathead County, at the western edge of Glacier National Park, and in Beaverhead County, ten miles south of Dillon. The rather desultory prospecting which followed the failure of these first efforts carried the search into Teton and Chouteau counties. These first ventures lacked some of the essentials that make for success, and in no instance was there any production of oil or gas.

Baker-Glendive (Cedar Creek) anticline.—The first production of gas in Montana was from Dawson County, near Glendive (T. 15 N., R. 55 E.), when in 1913 a well owned jointly by the Consolidated Oil and Gas Co. and the Mid-West Oil Co. was drilled to a depth of 2345 feet, and at a depth of 840 feet gas was obtained, the estimated production being 1,000,000 cubic feet per day(112). The drill began in the Bearpaw shales on the Cedar Creek anticline, and probably went through the Colorado formation. The production came mainly from the sand 840 feet deep and to a less extent from two other sands in the same zone, which consists of about 30 feet of alternating shales and sands belonging to the Judith River formation.

Further development has proved three productive districts on the Cedar Creek anticline, the Glendive (Cedar Creek) field, the Baker field near Baker, Montana, and the Cabin Creek field which is located about half way between Baker and Glendive. Fourteen wells were drilled in the Glendive district, eight of which were productive. The gas is all used in Glendive for domestic and industrial purposes. Two wells have been completed and capped in the Cabin Creek field, one of them having an estimated production of 1,000,000 cubic feet daily. There are four productive wells in the Baker district which supply Baker with gas for domestic purposes and for the manufacture of carbon black, the production of which is estimated at 450 to 500 pounds daily.

Havre district.—Shortly after the discovery of gas at Glendive, a large gas well was drilled at Havre, Montana. Two wells had been drilled in 1914, which produced a little gas, but in July, 1915, a well in the SE¼ Section 33, T. 33 N., R. 16 E., about 2 miles northeast of Havre, assured commercial production by coming in with an estimated flush production of 10,000,000 cubic feet per day(113). This well was drowned shortly after by water from a rival well, but the completion of a fourth well with an initial production of 1,000,000 cubic feet per day, partially made good the loss. This fourth well still produces 250,000 cubic feet per day and with 500,000 cubic feet per day from the ninth well, completed in 1921, furnishes the entire supply

(112) U. S. Geol. Survey Min. Resources of the U. S., Part II, Non-Metals, 1913, p. 1454.
(113) U. S. Geol. Survey Min. Resources of the U. S., Part II, Non-Metals, 1915, p. 980.

of the Havre district. The wells were begun in the Judith River formation and were drilled into the Eagle sandstone from which the gas is derived.

Sweetgrass Hills area.—Prospecting near the Montana-Canadian line was stimulated by the discovery of gas in Alberta and the area between the Sweetgrass Hills and the International Boundary, was the site of considerable activity in 1915-1916. The first well drilled, the Montana-Canadian Well No. 1, was started in the Two Medicine formation, 200-300 feet above the Eagle sandstone, and at a depth of 1860 feet in the basal Colorado sandstone, a flush production of gas estimated at 4,000,000 cubic feet per day was obtained(114). The well was capped. Three other wells were drilled from two of which only "shows" of gas and oil were found, but from the third, known as No. 4 well, which went to a depth of 2085 feet, an estimated flush production of 600,000 cubic feet of gas per day was obtained at 1887 feet, and 2 barrels of oil per day at 1955-7 feet. The casings were pulled from the three wells drilled last and the field was abandoned, but it is understood that the present season will see further testing of the region.

Elk Basin.—The first productive oil field in Montana was discovered in 1915 when the Elk Basin wells were drilled. The development of the district was rapid and by the end of 1916 the peak production was reached, ten producing wells having been completed and the limits of the field determined. The immediate effect was to turn attention to the Montana extension of Bighorn Basin. Wells were drilled in various localities, but none were successful and the period from 1916 to 1919 witnessed a marked decline in prospecting.

Present stage and development.—The recent revival of interest in oil and gas began when the well drilled by the Tri-City and Van Duzen Oil Companies in Section 29, T. 8 N., R. 21 E., on the Woman's Pocket anticline went through the red beds of the Kootenai formation and found a little heavy, black oil in the underlying Quadrant sands. Although there was no commercial production, the finding of oil was the basis of a hope that production could be secured from the Quadrant in other places and in November, 1919, the Van Duzen "Discovery Well" in Devil's Basin (Sec. 24, T. 11 N., R. 24 E.), found showings of oil in the Quadrant. It was not until the spring of 1920, however, that commercial production of oil was really assured from other than the Elk Basin field. Prospecting on the anticlines lying north of the Devil's Basin anticline resulted in the discovery of a high grade paraffin base oil in the Mosby dome. The Mosby structure is situated on the Cat Creek anticline, which extends from Black Butte (one of the Judith Mountain laccoliths) easterly and southeasterly beyond

(114) Billings, Paul, Personal communication.

PLATE VIII.—WEST MOSBY DOME.

This shows a typical exposure of Colorado shale along the low hills in the background being formed by the Eagle sandstone which here dips northeasterly rather steeply.

Musselshell River. Along the crest of the anticline are several upwarps or domes. The largest upwarp situated at the east end of the anticline is itself further subdivided into three domes, called the West Mosby, Mosby, and East Mosby domes.

The first discovery along the Cat Creek anticline was made in the Mosby dome, but subsequent work has not been so successful there as in the West Mosby dome, where there has been a rapid and successful development. By April 1, 1921, 27 wells had been completed in the West Mosby dome and from 25 of them, including the "discovery" well, oil is being obtained, whereas during the same time in the Mosby dome in only two wells has oil been found.

The Colorado shales are exposed in the Mosby field and oil occurs at a depth of 1100 to 1300 feet in the basal Colorado and underlying Kootenai sands. As yet no oil sand has been found on the Cat Creek anticline lower than the Kootenai, although a well has been drilled part way through the Quadrant on the upwarp known as the Kootenai dome, which lies about 24 miles west of the West Mosby dome.

The wells in the West Mosby dome have been brought in with a uniformly high flush production (reported as high as 2500 barrels per day) but decrease rapidly to a much lower settled production. The flow is held in tanks situated on the producing properties which in turn are connected with pipe lines running to Winnett, Montana, a branch terminal station on the Chicago, Milwaukee & St. Paul Railroad, whence the oil is shipped to Greybull, Wyoming, for refining. A 2-inch and a 4-inch pipe line have been laid from the field to Winnett.

The latest discovery of oil in Montana was made in the Soap Creek anticline, 28 miles south of Hardin on the Crow Indian Reservation. The structure is a small parallel flexure on the northeast flank of the Bighorn Mountain uplift. The Colorado formation outcrops at the surface(115) and the oil was found at 1642 feet in the Quadrant sands (equivalent to the Tensleep or Embar). The oil is reported to be a heavy, black oil, comparable to that secured in the Lander, Wyoming field, from the Carboniferous beds. On account of the lack of transportation facilities there is no production from this well, although it is estimated to be capable of producing 100 barrels per day.

Development work in Montana is not confined to these producing areas. Hundreds of local companies have been formed to prospect for oil in many localities, and many larger oil companies are engaged in extensive exploration. The whole of the plains area of Montana is receiving attention and the development of the oil and gas resources should be rapid.

(115) Billingsly, Paul, Personal communication.

Production.

The amount and value of gas and petroleum produced in Montana is shown by the following tabulations which have been made as accurate as possible by consulting all available data.

Gas.—There are three productive gas fields in Montana: Glendive, Havre, and Baker. The production of each is not shown separately but has been totaled to give the yearly production from Montana.

Year	M. Cu. Ft. Produced	Ave. Price Per M Cu. Ft.	Value	Consumers		Wells Drilled		Wells Abandoned	Producing Wells
				Domestic	Industrial	Dry	Productive		
1915	5,555	$0.4500	$ 2,500.00	1	1	.....	2	.....	†5
1916	213,315	.1821	38,855.00	727	6	.....	9	.....	‡11
1917	334,421	.2434	81,406.00	1216	12	2	3	1	13
1918	177,039	.3510	62,148.00	1198	.....	.....	.....	.....	§
1919	*240,000	No data	*110,000.00	.....	.....	.....	.....	.....	**
1920	*240,000	No data	*100,000.00	.....	.....	.....	.....	.....	**

*Estimated.
†Three poductive wells drilled in 1914.
‡Three wells not utilized,
§No data on drilling operations.
**Complete data lacking.

Petroleum.—Until 1920 the total production of oil in Montana came from Elk Basin but the production from the West Mosby dome now overshadows that from the older field, totaling in 1920, 236,832½ barrels, at an average price of $3.10 per barrel, valued at $734,180.75.

Year	Bbls. Produced	Ave. Price Per Bbl.	Value	Wells Drilled		Abandoned Wells	Wells Producing	Reramrks:
				Dry	Productive			
1915	0	.....	$.....	0	4	0	.....	No facilities for ship'g oil
1916	44,917	$0.98	44,019	1	2	0	6	Began shipping in June
1917	99,399	1.47	146,272	1	1	0	7	
1918	69,323	1.81	125,328	.....	.....	.....	.....	
1919	*84,000	No data	*170,000	.....	.....	.....	.....	
1910	*336,000	No data	*1,000,000	.....	.....	.....	.....	

*Estimated.

The price of crude Elk Basin oil at the beginning of 1919 was $1.85 and was $2.25 at the close of 1919, but rose to about an average of $3.00 during 1920.

Theoretical Considerations

A knowledge of the conditions controlling the accumulation of oil and gas is essential to an intelligent exploration of new oil and gas

fields. The essential conditions are: (1) a source of oil and gas, (2) a porous stratum, known as a reservoir rock in which the oil and gas can accumulate, (3) an impervious stratum, cap rock, sealing the reservoir rock, so as to prevent the escape of oil and gas, and (4) an enclosed structure into which the oil and gas may migrate from adjoining areas to form pools. Other factors or conditions may also affect the commercial accumulation of oil and gas, such as: the size of the drainage area, the absence of water in the oil sands, the depth of the oil sands, and the temperatures and pressures existing during the distillation of the oil and gas from their source. Following a discussion of the conditions enumerated, their application to the oil and gas possibilities of Montana is taken up.

Source of oil and gas.—Mineral oil, or petroleum, and natural gas are complex compounds of hydrogen and carbon, containing various impurities such as sulphur, nitrogenous substances, and oxidation products. They are classified into series such as the Methane or paraffin base series. To each series a generalized formula can be given, for example, that of the Methane series, C_nH_{2n+2}. The series begins with Methane gas (CH_4) and progresses according to the generalized formula, through the gaseous and liquid bitumens to the solid(116). When found in underground reservoirs, the gaseous bitumens form gas pools and the liquid bitumens oil pools.

Oil and gas have their source either in the distillation of organic material or in certain inorganic reactions. Belief in the inorganic theory would lead one to seek for oil and gas in areas more greatly deformed through mountain uplift or volcanic activity rather than in such areas as are now, through a general belief in the organic theory, considered promising.

There are three organic theories: (1) that oil and gas is derived from animal remains; (2) that it is derived from vegetal remains; and (3) that it is derived from both animal and vegetal remains. The last theory, called the Engler-Hofer Dual theory(117), is most generally accepted. The attempt to prove that oil and gas are derived from coal on account of the similarity between petroleum and natural gas and the distillation products of coal, is refuted by geologic evidence which shows that the oil producing horizons in most fields are not the coal horizons and are not in any way genetically connected with them. Furthermore, oil and gas are generally associated with marine formations and salt water, whereas coal is associated with continental deposits and fresh or brackish water. The part played by salt water in the origin of petroleum is uncertain. Some authors hold that it is essential as a preservative and precipitant, others hold that its pres-

(116) For details the writer is referred to Clarke, F. W., Data on Geol.-chemistry, U. S. Geol. Survey Bull. 695, or to various text books on Oil Geology or Chemistry.

(117) Engler and Hofer, "Das Erdol." Vol. 2, pp. 59-142, 1909.

ence is not necessary but only coincidental. The elimination of coal forming and land plants as a source of oil and the recognition of the association of oil and gas with marine sediments leads to the conclusion that plant and animal remains, which are deposited with marine sediments, are the source of oil and gas. These remains include spores, sea weeds, and soft parts of animals that yield waxy, fatty, gelatinous, and resinous products(118), and are ordinarily deposited with muds to form black shales. Although oil and gas may result from bacterial action it is not until the black shales have been heavily covered by younger sediments which, with the covering of salt water serve to prevent the rapid destruction of the organic matter by oxidation and to retain the products of decomposition, that, through heat and pressure, resulting from deep burial or deformation, oil is distilled from the organic matter(119). The presence of petroliferous rocks may be detected at the surface by the occurrence of oil or gas seeps or asphaltic residium or by actual outcrops of the petroliferous rocks, which may be recognized by their color, odor, or by chemical analysis.

Reservoir rock.—The formation of deposits of commercial importance requires the presence of porous rocks in which the oil and gas generated from the organic matter can accumulate. The amount of oil and gas, and the ease with which it can be secured, depends directly upon the number, size and shape of the pores. The most common reservoir rocks are sandstones, those having the largest capacity consisting of loosely cemented, medium-sized, rounded quartz grains. Other porous rocks in which oil and gas may be found are porous limestones, fractured shales and vesicular lavas.

Since oil and gas migrate upward, the reservoir rocks are found above the source of the oil and gas. Therefore, the ideal reservoir bed is situated above the petroliferous shales, which are the source of the oil and gas. However, where the rocks have been folded into anticlines with steeply dipping limbs, oil and gas may migrate upward through cross fractures toward the crest of the anticlines, and enter porous beds, which normally occur below the petroliferous shales, the source of the oil, but which along the anticlines have been uplifted above the petroliferous shales on either side. Thus, in Montana and Wyoming oil is derived from the Kootenai and Cloverly sandstones which are stratigraphically lower than the Colorado shales, which are probably the source of the oil.

Cap rock.—A relatively impervious bed, usually of shale, must overlie the porous, reservoir bed in order to retain the oil and gas in the reservoir rock. Even a slight leak may have completely

(118) White, David, Late theories regarding the origin of oil: Bull. Geol. Soc. America, vol. 28, p. 778, 1917.

(119) White, David, Genetic problems affecting search for new oil regions: Bull. 153, Am. Inst. Min. Eng., 1919; and McCoy, A. W., Notes on the principles of oil accumulation: Journ. Geol., vol. 27, pp. 252-254, 1919.

drained the reservoir. Hence, where open fractures exist commercial accumulations of oil and gas are unlikely. On the other hand, some good fields, notably the Elk Basin field of Wyoming and Montana have been greatly broken by faults, which must have been closed or sealed by clay gouge, rock flow, or cementation.

Enclosed structures.—To prevent the farther migration of the oil and gas upward along the contact of the reservoir rock with its cap rock, it is essential that the cap rock completely surround the upper sides of the reservoir as well as cap it, so as to form an enclosed reservoir. Enclosed reservoirs are formed in several ways as is illustrated by figures 1 to 6, plate IX. The various enclosed structures or reservoirs have been classified by F. G. Clapp(120) as follows:

Class I—Where anticlinal and synclinal structure exists.
- (a) Strong anticlines standing alone.
- (b) Well defined anticlines alternating with synclines.
- (c) Structural terraces.
- (d) Local warpings on monoclinal dip.
- (e) Accumulations on monoclines, due to thinning out or change in texture of the sand.
- (f) Broad geanticlinal folds.
- (g) Overturned folds.

Class II—Quaquaversal structures.
- (a) Anticlinal bulges, or "cross anticlines."
- (b) Saline domes.
- (c) Volcanic necks.
- (d) Perforated domes.

CLASS III—Joint cracks.
- (a) Joint cracks in sedimentary rocks.
- (b) Joint cracks in crystalline rocks.

Class IV—Sealed faults.

Class V—Oil sealed in by asphaltic deposits.

Class VI—Contact of sedimentaries with crystalline rocks.

Drainage area.—As a reservoir is assumed to drain all the surrounding area which is underlain by beds that slope upward to the reservoir, the amount of oil and gas in any reservoir is controlled by the size of the drainage area. Hence it is clear that other things being equal that oil field is most productive which has the largest drainage area.

Water in oil sands.—It is uncertain what is the cause of the migration of oil and gas from their source to the reservoir, but it is generally conceded to be due to the migration of water carrying oil and gas with it, or forcing the oil and gas ahead of it. The compacting of the petroliferous muds into shales may force the water

(120) Bacon, Hamor, and others; Amer. Pet. Industry, p. 48, McGraw-Hill, 1916.

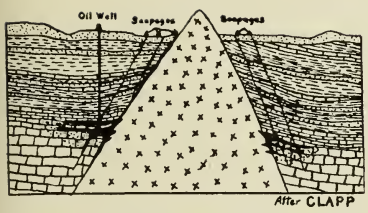

Fig 1.—Hypothetical cross-section of a Volcanic Neck in Mexico, showing the occurrence of petroleum according to Sub-class II (c).

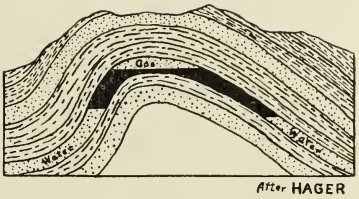

Fig. 2. Illustration of ideal anticlinal conditions, shsowing the occurrence of petroleum according to Class I.

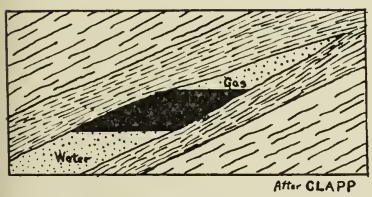

Fig. 3. Ideal section of a lenticular sand, showing the occurrence of gas and oil according to Sub-class I (e).

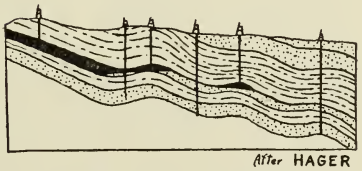

Fig. 4. Theoretical section, showing the occurrence of petroleum according to Class I. Note that the lower fold is non-productive, the oil having migrated up the slope.

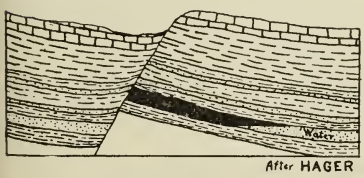

Fig. 5. Theoretical section normal to a fault plane, showing the occurrence of petroleum according to Class IV.

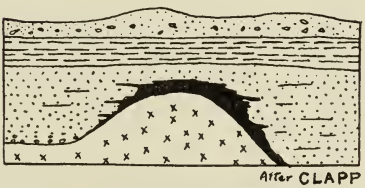

Fig. 6. Theoretical section of unconformable contact of Arkose on Granite, showing the occurrence of petroleum according to Class VI.

PLATE IX.—GEOLOGIC STRUCTURES FAVORABLE TO OIL AND GAS ACCUMULATION.

and oil and gas into the more porous beds that are not compacted so readily as the weaker muds(121), or as has been pointed out(122) water may through its greater capillary attraction replace the oil and gas in shales forcing the oil and gas into more porous beds.

Within the porous beds of the reservoirs the mixtures or emulsions of gas, oil and water are separated and the various constituents arranged within the reservoir according to their respective densities, the gas on top, underlain by the oil, and that in turn underlain by water. Where the oil sands are only partly saturated with water, oil and gas may be found in the limbs of the enclosed structure and in dry sands, as in places in the Appalachian region, may be found even in the troughs of the synclines.

Depth of oil sands.—Where, within the enclosed structure, erosion has progressed to such an extent that the oil sands occur at the surface, the oil and gas which may have been in the sand would have escaped. In almost every oil district there are usually monuments, in the shape of non-productive wells, where drilling began at or below the productive horizon. At several places in Montana, even where only the upper part of the Kootenai formation is exposed as in the Koontenai, Devil's Basin and Shawmut domes, no oil has been obtained from the Kootenai sandstones.

On the other hand, since the profitable extraction of oil and gas depends upon the cost or depth of drilling, the oil sands may be so deep as to preclude profitable development. Whereas wells have been drilled to a depth of over 7000 feet, yet it is doubtful if profitable wells can be drilled anywhere at the present time to more than 5000 feet. Furthermore, since the per foot cost of drilling increases rapidly below a few hundred feet with increasing depth, deep wells to be profitable must be large, long-lived producers. The limit of profitable drilling is of course subject to much variation, depending upon such conditions as labor costs, efficiency of the drill, character of the rocks, production and life of the wells, and price of crude oil. The limit in Montana or even in Wyoming has not yet been definitely determined but is probably not much greater than 3500 feet.

Physical conditions existing during distillation.—It is obvious that the character and amount of the oil and gas in any region is also dependent upon the physical conditions, temperatures and pressures, existing during the distillation of oil and gas from their source, since distillation results largely from heat and pressure. Because the character of a coal is also dependent largely upon the temperatures and pressures to which it has been subject, passing under their influ-

(121) Daly, M. R., The disastrophic theory: Bull. Am. Inst. Min. Eng., No. 115, pp. 1137-1157, 1919.

(122) McCoy, A. W., Notes on principles of oil accumulation: Journ. Geol., vol. 27, pp. 252-262, 1919.

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ence from its initial stage of peat through lignite, sub-bituminous and bituminous coals and to the higher grade coals and even to graphite, White(123) has suggested the use of the character of the coals in any region as an index or gauge of the physical conditions. Coals are classified according to the ratio, called the fuel ratio, of the amount of fixed carbon to the amount of volatile matter they contain, or by the percentage of fixed carbon in pure ash and water-free-coal. Thus lignite usually contains less than 50 per cent fixed carbon, sub-bituminous coal from 50 to 60 per cent, bituminous coal from 55 to 75 per cent, and the higher grade coals more than 75 per cent. Detailed study by White as well as by Fuller(124) and Gardner(125) in the Appalachian and Mid-Continent fields with a more general study of the other oil fields of the world has shown that although fields of heavy oils occur, as in the coastal plain of Texas, where the percentage of fixed carbon is less than 50 per cent, in the principal fields of medium oils like those of the Ohio-Indiana and Mid-Continent fields, the amount of fixed carbon varies from 50 to 55 per cent and in the principal fields of light oils and gas of the world, like the Appalachian field, the amount of fixed carbon varies from 55 to 60 per cent. Where the amount of fixed carbon varies from 60 to 65 per cent, commercial pools are rare, but the oil is exceptionally high grade when found; gas wells are common but are usually isolated. Where the amount of fixed carbon exceeds 70 per cent, oils, if present, will be "white oil" (approximately kerosene) in pockets too small to be of commercial importance though gas pockets may exist.

Although first advanced in 1915, practically no exception to Dr. White's principle of the distribution of oil has been discovered. Since the heat and pressure causing the devolatization of coals and the distillation of oil and gases results largely from deformation, in greatly deformed, mountain built regions, the carbonization of the coals is usually above the 65 to 70 limit, or "dead line." Although as White(126) points out, the carbonization ratio applies only to areas in which alteration is regional, that is caused by deformation, not contact metamorphism resulting from the intrusion of igneous rock bodies, yet igneous intrusives such as occur throughout the mountains of Montana, although more local in their effect bring about similar changes to deformation. Furthermore, the escape of hot waters or solutions from the igneous intrusions, usually fill the pores of the adjoining rocks with mineral matter converting reservoir rocks into

(123) White, David, Some relations in origin between coal and petroleum: Wash. Acad. of Sci., vol. 6, pp. 189-212, 1915.

(124) Fuller, M. L., Relation of oil to carbon ratios of Pennsylvanian coals in North Texas: Econ. Geology, vol. 14, pp. 536-542, 1919, and Carbon ratios in Carboniferous coals of Oklahoma, and their relation to petroleum: Econ. Geology, vol. 15, pp. 225-235, 1920.

(125) Gardner, J. H., The Mid-Continent oil field: Bull. Geol. Soc. America, vol. 28, pp. 685-720, 1917.

(126) White, David, Genetic problems affecting search for new oil regions: Mining and Metallurgy, No. 158, Sec. 21, p. 7, Feb., 1920.

firm, impervious rocks such as quartzites, in which no accumulation of oil and gas can take place.

In conclusion it is well to consider that owing to the many conflicting or compensating conditions, many of them imperfectly understood, affecting the commercial accumulation of oil and gas, "it is not surprising that some concentrations of oil and gas occur where, from all surface indications (especially where the productive rocks are obscured by a mantle of younger, unconformable sediments) the conditions are unfavorable, whereas, some areas that appear to have the most favorable structure are barren."(127)

Possibilities of Oil and Gas.

This chapter on the possibilities of oil and gas must serve as a guide in detailed work rather than as a final report on any area, as the reconnaissance nature of the field work precludes detailed discussions. As already noted, the possibilities will be discussed by applying the theoretical conditions presented in the previous section, to Montana.

Sources of oil and gas.—The marine shales of the Claggett and Bearpaw formations are the only rocks above the Colorado formation which need to be considered as sources of oil and gas as the sediments of the Eagle, Judith River, Lance, and Fort Union formations were deposited under littoral or continental conditions and are not known to contain any black, bituminous shales. Some such shales do occur in the Claggett and Bearpaw formations and Hancock(128) has reported surface indications of oil and gas in the vicinity of Hardin and in the northwest corner of Yellowstone County. However, no commercial amount has ever been found and it is doubtful if either the Bearpaw or Claggett shales can furnish any significant quantity of oil or gas. Furthermore, to the west the shales grade into alternating sandstones and shales typical of near shore or litoral deposits.

The source of most of the oil and gas produced in Wyoming and southern Alberta is generally conceded to be the black shales of the lower portion of the Colorado formation. The uninterrupted continuation of the Colorado formation from Wyoming through Montana into Alberta has long been considered the most favorable indication that Montana would produce oil. Recent drilling has shown, however, that in places the lower black shales are absent. Stebinger's field work(129) in the northwestern part of the plains area has shown some of the Colorado shales to be petroliferous to such an extent that

(127) Hancock, E. T., Geology and ol and gas prospects of the Huntley field, Montana: U. S. Geol. Survey Bull. 711-G, p. 146, 1920.

(128) Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Montana: U. S. Geol. Survey Bull. 711-G, p. 144, 1920, and Geology and oil and gas prospects of the Lake Basin field, Montana: U. S. Geol. Survey Bull. 691-D, p. 126, 1918.

(129) Stebinger, Eugene, Oil and gas geology of the Birch Creek-Sun River area, northwestern Montana: U. S. Geol. Survey Bull. 691-E, p. 157 and pp. 161-164, 1918.

they offer an unquestioned source for commercial quantities of petroleum. The main petroliferous horizon seems to be confined to the lower 150 feet of shales which overlie the Blackleaf sandy member. Collier(130) states of the Mowry member, "it seems almost certain that the formation would yield oil if properly sampled and tested." These reports from the northwestern and northeastern parts of Central and Eastern Montana, in connection with the fact that the major production from Wyoming and the entire production from the Mosby dome in Central Montana is from associated sands, indicate that the Colorado formation and in particular the Mowry member, is the important source of oil and gas in Montana. In all places the oil is a high grade, light oil with a paraffin base and in Central Montana consists mainly of gasoline and kerosene.

Since the Mesozoic sediments below the Colorado formation are predominantly sands and shales of continental and near shore origin it is doubtful that any petroliferous beds competent to serve as sources of oil or gas will be found. Furthermore no oil or gas other than that which has migrated from other sources, have been discovered in these formations.

Two possible sources of oil and gas are found in the Paleozoic sediments. Although the more northerly exposures of the Quadrant formation in Central Montana do not show a dominately petroliferous zone, yet some black shales which may have furnished oil and gas are found and the more westerly and southerly exposures are of a more favorable character. The phosphatic black shale member of the Quadrant, which contains the oil shales of southwestern Montana is reported to thin to the eastward(131) and whereas the Quadrant sands have not yet furnished commercial production in Musselshell Valley, yet these beds are productive in the Soap Creek anticline. Along Mackenzie River in Canada, numerous seeps of light to heavy asphaltic petroleums are found in the Devonian limestones. To the south, along Athabasca River, these beds are overlain by Dakota sandstones which are known as "tar sands" due to their saturation with asphaltic bitumens which appear to have been derived from the underlying limestones. Southward, in Montana, the Devonian beds are exposed only in the western mountainous area but underlie at least a part of the plains area. Peale(132) describes them as black magnesian limestones "crowded with Devonian fossils," and shales which in places form carbonaceous phases of sufficient richness to form an impure coal.

Reservoir rocks.—Porous beds which may serve as erservoirs are known at various horizons in the upper Paleozoic and Mesozoic forma-

(130) Collier, Arthur J., The Bowdoin Dome, Montana, a possible reservoir of oil or gas, U. S. Geol. Survey Bull. 661-E, p. 199, 1917.
(131) Condit, D. Dale, Oil shale in western Montana, southeastern Idaho, and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 711-B, p. 20, 1919.
(132) Peale, A. C., Three Forks Folio, U. S. G. S., Folio 24, 1986.

tions. The oil that might be generated in the Paleozoic sediments finds suitable reservoir rocks in the Quadrant formation, correlated with the Tensleep, Amsden, and Embar formations in Wyoming. The most important reservoir rocks belong to the Comanchean and Cretaceous series and serve as collecting sands for oil and gas derived from the associated Colorado shales. The present productive sands occur in the Colorado and Kootenai formations underlying the Colorado shales, in the Eagle sands overlying the Colorado shales, and in the Judith River formation overlying the Claggett shales. The Frontier sands, from which most of the oil in Wyoming is obtained, are only locally developed in Montana and have not yet proved to be productive in Montana except in the Elk Basin dome. The basal Colorado sandstone or "Rusty Beds" is the first of the three oil sands of the Mosby district, and the first and second Kootenai sandstones are the two lower sands. The production from the West Mosby dome is almost entirely from the upper sand, whereas the production from the Mosby dome proper, or middle dome, is from the middle sand. Oil has been obtained from the lowest sand in the Ten Spot well on the West Mosby dome near the edge of the productive area. The chances for production from the two lower sands in the West Mosby dome are therefore favorable.

The Eagle sandstones are productive of gas in the Havre district but are not known to contain oil. Since they are separated from the basal petroliferous beds of the Colorado by 1500 to 2000 feet of clay shales, which are not readily traversed by fractures open sufficiently to allow the migration of oil through them, it is doubtful if the Eagle sandstones contain any significant amounts of oil anywhere in Montana. Where traversed by large faults, as in the Havre district, gas can doubtless migrate through the Colorado shales, and may collect in the Eagle sandstones in commercial quantities.

The Judith River sandstones also contain commercial amounts of gas in the Cedar Creek anticline, but are still farther separated from the source of the oil and gas than the Eagle sandstones, and hence are not likely to contain oil. In fact it appears as if the Judith River sands are productive of gas in the Cedar Creek anticline because the Eagle or other sands are lacking between the Judith River sands and the source of the gas in the basal Colorado shales. It would be unwise, therefore, to prospect only the Judith River sands in those areas also underlain by the Eagle sands.

Cap rocks.—Extensive thick beds of shale occur throughout the sedimentary series of Central and Eastern Montana. Most of the shales are weak and incompetent and hence, will flow when under the weight of only a few hundred feet of overlying sediments. Therefore, although they may be broken by faults in many places, they may still serve to cap the underlying sandstones effectively.

Favorable structures.—With a minor exception in southwest Wyoming, the only structures which have proved to be productive of

oil in Montana or Wyoming are domes or enclosed anticlines, although within these structures the actual distribution of oil is controlled in places by faults. The uplifts terminated on one side by faults, to the north and south of the Bearpaw mountains, contain gas but have not yet been proved to contain commercial amounts of oil. The major structural features have already been described(133) and are shown and named on the accompanying structural map. Whereas the possibilities of oil and gas in each of the structures can not be discussed, on account of the lack of detailed knowledge, yet the application of the facts and theoretical principles already given may be considered further, profitably.

Since, as already described, the principal sands, the basal Colorado and Kootenai, in which oil is now found in Montana occur lower in the geologic column than the principal source of the oil, the Mowry member of the Colorado, the most favorable structures are those with steep limbs, affording a chance for the oil to migrate upward through cross fractures toward the crest of the fold where the sands have been uplifted above the petroliferous shales. Even in Wyoming where the Frontier sands are well developed, no large oil fields have been found except where the dips exceed at least 10 degrees in places. In Montana the folds of steep dips occur chiefly in connection with the main Rocky Mountain uplift, the major axis of deformation of Central Montana south of the Little Belt mountains, and the synclinal area between this axis and the main mountain uplift, the Big Snowy Mountains anticlinorium, and in the north and south of the Bearpaw Mountains as well as in the Sweetgrass Hills, Bearpaw Mountains, and Little Rocky Mountain uplifts. In the Sweetgrass arch, and west to the area of greatly folded and faulted rocks near the Lewis overthrust fault and in Eastern Montana the dips are usually less than 5 degrees. However, the western limb of the Cedar Creek anticline dips at an average angle of 20 degrees. On the Sweetgrass arch, and the Porcupine dome as well, a few minor uplifts or domes are reported, and it is possible that some of them will have sufficiently steep dips to be worth testing.

However, it must be borne in mind that in general where the folds have the steepest dips they are close together and only a relatively few enclosed anticlines and domes with steep dips have a sufficiently large drainage to have collected commercial amounts of oil and gas. It is doubtful if any of the folds within the main mountain area, or even close to the main mountain front, have a sufficiently large drainage area, and doubtless this cause is one of the reasons for the failure resulting from drilling in the Woman's Pocket and Shawmut anticlines, Big Coulee-Hailstone dome and the domes on the Elk uplift, all situated along the axis of major folding in Central Montana between the Bighorn and Little Belt and Big

(133) See pages 18-24.

Snowy mountains. This element in the problem should also be given careful consideration in the location of test wells on the faulted structures to the north and south of the Bearpaw mountains. On the other hand, the domes along the north and south margins of the Big Snowy anticlinorium, on the flanks of the Bighorn mountains, and in the synclinal area to the west, and in Eastern Montana all have large drainage areas.

Virtually all of the sandstones of Central and Eastern Montana are saturated with water throughout their entire extent and although one or two wells have been driven into dry sands, yet the chances are that within nearly all the enclosed structures of Central and Eastern Montana, the sands contain sufficient water to have caused the migration of oil and gas from the surrounding drainage area to the apex of the structure.

In all of the mountain groups of Central Montana, with the exception of the western portion of the Bearpaw, and the Highwood and Crazy mountains which are largely volcanic in character, Madison limestone and older Paleozoic rocks and even igneous rock cores are exposed. Hence, they cannot be considered favorable to the accumulation of oil and gas. Furthermore, in some of the otherwise fairly favorable structures, such as the Kootenai and Devil's Basin domes and the West and Middle domes of the Shawmut anticline, the Kootenai formation is exposed and drilling has failed to secure oil from the shallow Kootenai sands although some oil has been obtained from the much more deeply buried Quadrant sands.

The lowest rocks exposed in the structures of Eastern Montana, and in several of the structures of Central Montana, except in the Porcupine dome and in northern extension of the Black Hills uplift in southeastern Montana, occur above the Colorado formation. Therefore, to test the basal Colorado and Kootenai sands, the highest known oil horizons in Montana except the Frontier sand in the Elk Basin dome, it will be necessary to go through the Colorado formation which has a thickness of 1500 to 2200 feet. Where the Bearpaw shales are the lowest exposed formation, as in several of the structures of Eastern Montana, and a few in Central Montana, it will be necessary to go through the additional thickness of the Eagle, Claggett, and Judith River formations amounting from 600 to more than 1200 feet. Throughout Central and Eastern Montana, the base of the Colorado formation is at least 2000 feet below the base of the Bearpaw shale and in most places is nearly 3000 feet or more. Where the Lance formation is the lowest rock exposed, the Bearpaw shales must also be penetrated so that the depth to the base of the Colorado will vary from 3000 to more than 4000 feet. Since it is doubtful if oil can be produced at a profit in Montana from depths of more than 3500 feet, drilling for oil in structures where the Lance is the lowest exposed rock cannot be recommended at the present time and not until further development has proved the existence of oil in neigh-

boring structures where the oil sands are shallower. Gas, however, may be sought at shallower depths, 1500 to 2000 feet less in the Eagle sand, and 2000 to 2500 feet less in the Judith River sand.

On the accompanying index structural map, the lowest exposed formation is given with the name of the structure and also four type geologic sections, referring in particular to those parts of the state where the corresponding figures are shown. Thus, by the use of the data given, a rough estimate of the depth of the various sands in any structure may be made.

There are an insufficient number of analyses of coal from carefully selected places to determine accurately the physical conditions under which oil and gas might have been distilled in various portions of the state by plotting the carbon contents of the pure coals. In general the carbon content of the lignites of Eastern Montana is slightly less than 50 per cent, hence, any oil which may be found in Eastern Montana will probably be of a heavy character. The carbon content of the sub-bituminous coals of the western part of Eastern Montana and the sub-bituminous and bituminous coals of Central Montana, except close to the mountain uplifts, ranges from 50 to 60 per cent and hence represent ideal conditions for the distillation of medium and high grade oils such as have already been found. Close to the mountains and in the eastern part of the Rocky Mountains the carbon content of the bituminous coals range from 60 to 72.5 per cent, although in places, as in the Trail Creek field(134), the carbon content may be as low as 53.5 per cent, and hence the region cannot be considered as favorable in general to the occurrence of oil in quantity although some high grade oil and gas may be found. There are virtually no analyses from which to judge the carbon content of coals, hence the metamorphic conditions, existing well within the mountain region, but in most places it would doubtless exceed the "dead-line" of 70 per cent.

It cannot be denied that the results of drilling during 1920 and the first half of 1921 have been disappointing. Several structures where apparently the surface indications have been favorable have not yet been proved to contain oil and possibly some have been definitely disproved, and by June 1st, 1921, only the Elk Basin dome, the West and Middle Mosby domes, and the Soap Creek dome, have been proved to contain oil in profitable amounts. On the other hand it can be said in all fairness that where competent examination shows in Central or Eastern Montana an enclosed structure with steeply dipping limbs, with a good drainage area, and with Judith River or lower Cretaceous rocks exposed, there is ample justification for a test well.

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(134) Calvert, W. R., The Livingston and Trail Creek coal fields, Montana; U. S. Geol. Survey Bull. 471-E, p. 402, 1912.

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COLUMNAR SECTIONS

1 (After Stebinger)

Lance Shale and Sandstone	1000' ±
Bearpaw Shale some Sandstone	500' ±
Two Medicine Shale, Sandstone and some coal.	2000' ±
Eagle Sandstone	290' ±
Colorado Shale some Sandstone	1800' ±
Kootenai-Morrison Sandstone and Shale	900' ±
Ellis Shale, Limestone and Sandstone	275' ±

2 (After Collier)

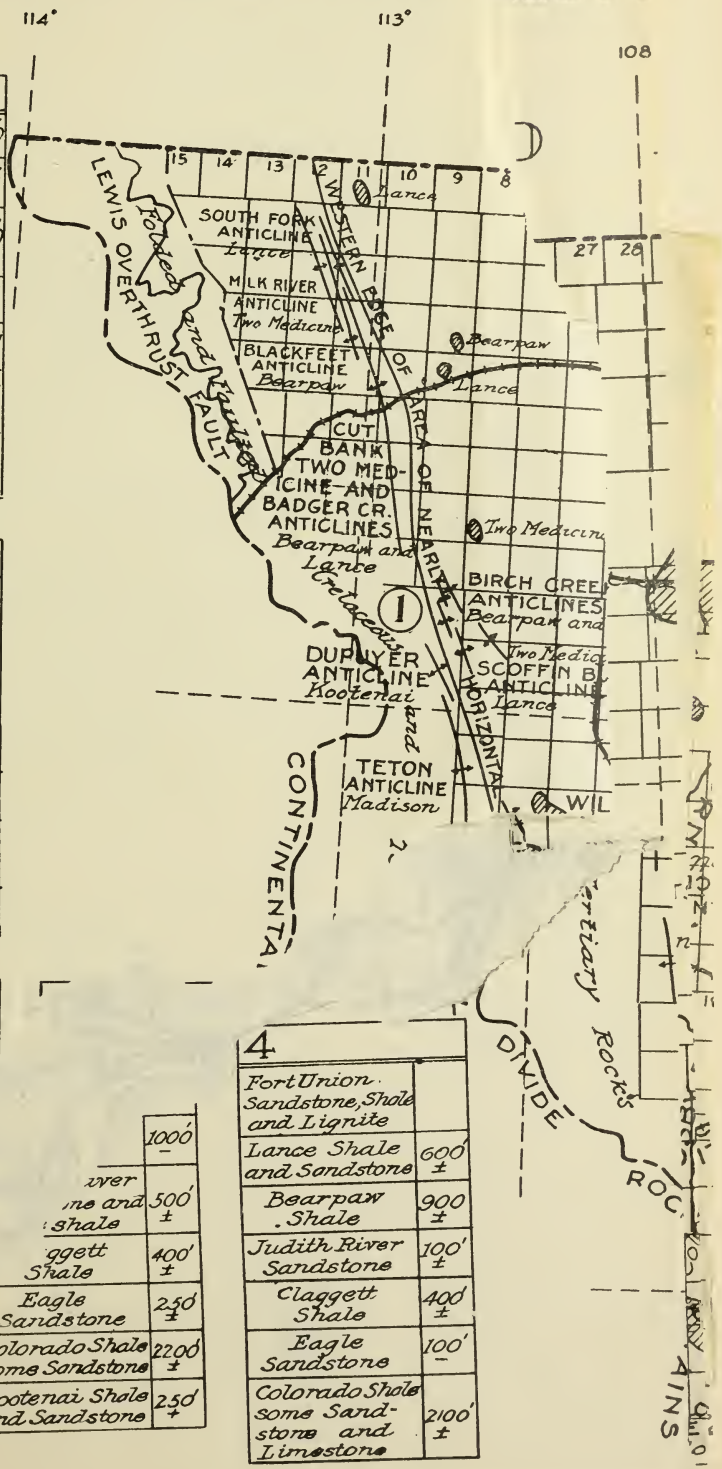
Bearpaw Shale	900' ±
Judith River Sandstone	400'
Claggett Shale	750'
Eagle Sandstone	100' ±
Colorado Shale some Sandstone	1500' ±
Kootenai-Morrison Sandstone Shale	825 ±
Ellis Sandstone and Shale	400 ±

3 (After Bowen)

Lance Shale and Sandstone	1000' ±
Bearpaw Shale	
Judith R. Sandstone some Cla	
	1000'
ver ne and Shale	500' ±
ggett Shale	400' ±
Eagle Sandstone	250' ±
Colorado Shale some Sandstone	2200' ±
Kootenai Shale and Sandstone	250' ±

4

Fort Union Sandstone, Shale and Lignite	
Lance Shale and Sandstone	600' ±
Bearpaw Shale	900 ±
Judith River Sandstone	100' ±
Claggett Shale	400' ±
Eagle Sandstone	100' –
Colorado Shale some Sandstone and Limestone	2100' ±



Map of Central and East MONTAN showing Major Geologi Structures

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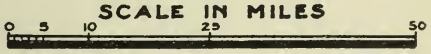

UNIVERSITY OF MONTANA BULLETIN
BUREAU OF MINES AND METALLURGY SERIES NO. 5

THE LOCATION, REPRESENTATION AND PATENTING OF MINERAL LANDS IN MONTANA

PROSPECTING AND LEASING OF COAL, OIL, OIL SHALE, GAS, PHOSPHATE AND SODIUM DEPOSITS

By A. E. ADAMI.

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AUGUST 1923

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STATE BUREAU OF MINES AND METALLURGY.

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PUBLICATIONS.

No. 1. The Montana State Bureau of Mines and Metallurgy (an explanation of its purpose and operation).

No. 2. Directory of Montana Metal and Coal Mines.

No. 3. Mechanical Ore Sampling in Montana (by H. B. Pulsifier).

No. 4. Geology and Oil and Gas Prospects of Central and Eastern Montana (with a geologic map). (By C. H. Clapp, Arthur Bevan, and Gerald S. Lambert).

No. 5. The Location, Representation, and Patenting of Mineral Lands in Montana.

Prospecting and Leasing of Coal, Oil, Oil Shale, Gas, Phosphate, and Sodium Deposits. (By A. E. Adami).

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PREFACE.

This bulletin deals mainly with interpretations of the federal and state mining laws as related to the discovery, location, representation, and patenting of mineral land in the state of Montana. Considerable space has been given to rules and regulations pertaining to the Leasing Act, as approved by Congress on February 25, 1920, which relates to the mining and prospecting of mineral deposits of coal, phosphate, oil, oil shale, gas and sodium. The last part of the bulletin includes many sections of the mining laws of Montana as taken from the Revised Codes of 1921. These sections treat with the laws of location and representation, and laws which apply to the actual mining of mineral deposits, and mine operations.

This work has been written with the intentions of supplying the prospector and locator of mineral deposits with such information as will aid him in complying with the laws from the time of discovery to such time as a patent is obtained, and to inform any qualified applicant as to the general procedure, necessary to prospect and lease lands containing mineral deposits as covered by the Leasing Act.

The information contained in this bulletin has been obtained from the Regulations of the United States Land Office, and from the various treatises on mining laws, namely, Lindley on Mines, Morrison's Mining Rights, Howell on Lode and Placer Claims, Ricketts on Mines, and Shamel on Mining, Mineral and Geological Law.

The writer wishes to acknowledge his indebtedness to these treatises, and to Dr. C. H. Clapp and Prof. W. T. Scott for their kind assistance in the preparation of this work.

The writer is especially indebted to Mr. Samuel Barker, Jr., E. M., and to Mr. E. B. Howell, LL. B., who have given their valuable time to reading the bulletin besides offering many valuable suggestions, and contributing knowledge gained from practice in their professions.

A. E. ADAMI.

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THE LOCATION, REPRESENTATION, AND PATENTING OF MINERAL LANDS IN MONTANA.

Mineral Land: Definition.

Land which has been classified as more valuable for its mineral deposits than for other purposes is called mineral land. In many cases land which is yet unclassified by the land department of the government may be more valuable for its mineral content than for other purposes and might therefore be called mineral land. In case of dispute, the final decision as to the true character of the land is made by the federal land department, or by the different courts.

Unappropriated land, upon or within which mineral is found, is not classed as mineral land unless the deposits are of sufficient size and value to warrant the expenditure of time and money for the purpose of prospecting and developing the deposits, and unless the land proves more profitable for mining than for other purposes.

Land Subject to Location in Montana:

All mineral land on the public domain of the United States within the State of Montana, whether surveyed or unsurveyed, is open to location. Following is Section 2319 of the Revised Statutes of the United States, as enacted on May 10, 1872, and which is still in force:

"All valuable mineral deposits in lands belonging to the United States, both surveyed and unsurveyed, are hereby declared to be free and open to exploration and purchase, and the lands in which they are found to occupation and purchase, by citizens of the United States and those who have declared their intention to become such, under regulations prescribed by law, and according to the local customs or rules of miners in the several mining districts, so far as the same are applicable and not inconsistent with the laws of the United States."

A valid location can also be made on a forest reservation.

State Lands: Location on

In Montana lode or quartz claim location may be made on mineral land owned by the state. A locator of state land must comply with the regular laws of the state pertaining to the location of claims, except that no notice of location need be recorded in the office of the County Clerk and Recorder, but should be filed with the Register of State lands. After one year the locator must purchase the claim at not less than $10.00 per acre, or lease the same from the State Board of Land Commissioners. The land must be mineral land and be more valuable for mining than for other purposes. A lode or quartz claim may not be located on any coal or oil lands belonging to the state. (See page 55.)

Lands not Subject to Location in Montana:

Any land which has been reserved by the government for military purposes, school purposes, for Indian reservations, or for public parks cannot be located for mineral. If a reservation has been abandoned by the government and restored to the public domain it is again subject to location.

Locations on Forest Reservations are not included in the above exceptions. A special act was passed by Congress dated March 3, 1891, withdrawing certain lands from the public domain for forest reservations, but in 1898 Congress passed another law whereby all mineral land in such forest reservations is subject to location and entry as mining claims.

Following is a list of Indian Reservations opened to the public, and therefore subject to location according to the mineral laws of the state:

Fort Belknap, Montana, June 10, 1896. (Minimum price per acre $10.00) Blackfeet Reservation, Montana, June 10, 1896. Flathead Reservation, Montana, April 23, 1904. Crow Indian Reservation, Montana, April 27, 1904. (Price of mineral land as provided by law, but in no case less than $4.00 per acre.)

Land which has been granted to a railroad, and for which title passed to the railroad company, is no longer free and open to location.

School Lands:

Congress has reserved Sections 16 and 36 in each township in the State of Montana, and has granted the same to the state for the maintenance of public schools, providing, however, that these sections have been classified by proper authority as non-mineral in character. The classification of the school sections is usually made immediately after they have been surveyed and approved. If the land is found to be mineral in character, it is not included in the grant, and is, therefore, open to location. If the land has been otherwise appropriated, or if a mineral location has been made before the land has been surveyed, it is likewise not included in the grant.

Agricultural Land:

Where a patent has been issued for a homestead, and title thus granted, it is impossible for a valid mineral location to be made, unless fraud has been committed in obtaining the agricultural patent. In case of fraud, a suit by the United States to vacate and annul patents, must be brought within six years after the date of issuance of patent, otherwise the patent is good. (Act March 3, 1891). If a valuable mineral deposit has been discovered on agricultural land for which patent has been issued, the deposit may not be located by a third party. Such a deposit can be worked or prospected only subject to the wishes of the owner under patent.

Before Patent is Issued:

If a homestead is applied for in the local land office, and patent has not been issued, it will be possible for a valid mineral location to be made providing, however, that sufficient mineral can be found. In case of dispute between the agricultural and mineral locators, it is necessary to have the Land Office determine the character of the land, and if

any portion of the land in conflict is proved to be mineral land by the legal authorities, it will be open to location, and the homestead entry for that portion in conflict will be cancelled.

Locations: Who may locate—

Citizens:

Any citizen of the United States or anyone who has declared his intention to become a citizen may locate mineral land for the purpose of prospecting and developing the same.

Aliens:

An alien may locate a claim in the State of Montana, and can hold, prospect, or develop it, and his rights will be protected by the laws in so doing, providing that he otherwise complies with the state laws governing the location of mining claims, and all ore that is discovered and mined may be sold or otherwise disposed of as desired by the alien locator. The Montana law states that:

"Any person who discovers, upon the public domain of the United States, within the State of Montana, a vein, lode, or ledge of rock in place, bearing gold, silver, etc., as a placer deposit of gold or other deposit of minerals having a commercial value, which is subject to entry and patent under the mining laws of the United States, may, if qualified by the laws of the United States, locate a mining claim upon such vein, lode, or ledge or deposit, etc."

In several cases, as decided by the courts, it has been held that a location by an alien is not void but voidable, [1]The right of an alien to hold a mineral location may be contested by the Government only, and an alien may, therefore, hold a claim indefinitely by right of location. Should the alien later declare his intention to become a citizen, his location would become valid, and his rights would date back to the time of location. An alien may purchase a patented claim in Montana, or acquire title to the same otherwise, in which case he has the same rights as any citizen.

Corporations:

Any association or partnership composed of citizens and corporations, organized under the laws of any state, or of the United States, may locate mining claims. A corporation is not legally considered an association, and therefore it may not locate a placer claim of more than twenty acres.

A valid location may be made by an agent for another person or persons, including corporations and partnerships. A minor, regardless of sex, may also locate a claim and hold the same.

United States Mineral Surveyors, officers, clerks, and employees of the General Land Office, may not locate nor patent a mining claim.

Number of Locations Allowed:

The number of locations that one person may make is unlimited by the state law, but as a prospector or locator is usually limited with capital and time, the number of claims that he may legally hold is more

[1]Howell on Lode and Placer Claims, page 7.

or less limited thereby. It is necessary that $100.00 be spent on each claim each year, or in case of a group of claims, the annual work for all of the claims may be performed under certain conditions, on any one of the claims if not less than $100.00 is spent for each claim so represented. This annual work is also known as "Representation Work". (See Location Page 20.)

Kinds of Claims:

Lands may be located, under certain conditions, for mining purposes as lode, placer, tunnel, millsite, coal, oil, oil shale, gas, phosphate or sodium claims.

Lode Claims:

Lode claims are understood to be mining claims on which valuable mineral has been found in place, and any mineral land on the public domain of the United States which has not been otherwise appropriated may be located as a lode claim. By the phrase "mineral in place" is meant mineral which is fixed or enclosed in the country rock.

The terms "vein", "lode", "lead", "ledge", are used synonymously by the prospector and locator, and hence may be considered synonymous when making locations, although from a geological standpoint, these terms are not identical in meaning.

A vein is a tabular or sheet-like mineral deposit found in connection with some pre-existing fissure or cavity. A lode or lead has been formed in connection with a series of nearly parallel, closely spaced fractures, and may therefore, consist of several veins. A ledge refers to a vein having a large and prominent outcrop.

Placer Claims:

A placer claim may be a claim located on mineral land containing mineral deposits in a loose state, that is not in place. Mineral deposits found in a loose state may be rightly called placer deposits. According to the laws of the United States, the following minerals may be located as placer deposits: alum, asphaltum, diamonds, guano, gypsum, kaolin or china clay, marble, mica, onyx, slate, building stone and limestone for fluxes or smelting purposes. Clay used for manufacturing brick is not considered a mineral, and such clay deposits must be located as agricultural land. Abandoned tailings may be located as a placer deposit.

Tunnel Claims:

A tunnel claim is one located for the purpose of prospecting mineral land by means of a tunnel. All veins cut by the tunnel are subject to location and development by the prospector providing no prior rights to the vein existed before beginning the tunnel. A tunnel may not be driven through any ground which was located by another party prior to the date the tunnel was started, nor may it be driven through any ground for which another person has a patent. Following is section 2323 of the Revised Statutes of the United States, as passed on May 10, 1872, regarding tunnel claims:

"When a tunnel is run for the development of a vein or lode, or for the discovery of mines, the owners of such tunnel shall have the right

of possession of all veins or lodes within 3,000 feet from the face of said tunnel on the line thereof, not previously known to exist, discovered in such tunnel, to the same extent as if discovered from the surface; and locations on the line of said tunnel of veins or lodes not appearing on the surface, made by other parties after the commencement of the tunnel, and while the same is being prosecuted with reasonable diligence, shall be invalid, but failure to prosecute the work on the tunnel for six months shall be considered as an abandonment of the right to all undiscovered veins on the line of such tunnel."

By "face" is meant the working face of the tunnel when it is entirely under ground or actually under cover.

Millsites:

A millsite is a tract of land not exceeding five acres, located on non-mineral land but not contiguous to one's lode location. If the millsite is located with a lode claim it may be used in connection with the lode claim for mining and milling purposes. A millsite may also be located by an owner of a quartz mill or other reduction plant, who does not own a mine or lode claim in connection with the reduction plant.

Section 2337, Revised Statutes of the United States, as passed May 10, 1872, states:

"Where non-mineral land, not contiguous to the vein or lode, is used or occupied by the proprietor of such vein or lode for mining and milling purposes, such non-contiguous surface ground may be embraced and included in an application for patent for such vein or lode, and the same may be patented therewith, subject to the same preliminary requirements as to survey and notice as are applicable to veins or lodes; but no location hereafter made of such non-adjacent land shall exceed five acres, and payment for the same must be made at the same rate as fixed by this chapter for the superficies of the lode. The owner of a quartz mill or reduction works, not owning a mine in connection therewith, may also receive a patent for his millsite, as provided in this section."

It is absolutely necessary that the land claimed as a millsite be non-mineral in character, and therefore, it should not contain any veins, lodes, or ledges valuable for mineral. By "contiguous" is meant adjoining, adjacent, touching. A claim and millsite with only one corner in common has been held as not contiguous.

Coal Land on State Land:

All known or classified coal land now owned or acquired later by the State of Montana is reserved from location and can only be leased from the State by paying a royalty of not less than ten cents per ton to the State. State coal lands are so classified by the United States Geological Survey and by the State Board of Land Commissioners.[1]

Coal Claims on Government Land in a State: (See page 42.)

Oil and Gas Land: On State Land—

All state lands are subject to sale, or lease but all coal, oil and gas contained therein is reserved by the state. (See page 56.)

On Government Land:

By an act passed in Congress in 1903 oil lands were located as placer claims and the annual assessment work on a group of claims not exceed-

[1]Laws of 1909, Chapter 147. See pages 56 and 57.

ing five in all, lying contiguous and owned by the same person or corporation, was done on any one claim, provided that the work performed developed the adjoining claims.

By an act as approved by Congress on February 25, 1920, all lands containing coal, oil, and gas, owned by the United States, are subject to lease only by citizens of the United States and under certain conditions by citizens of a country which grants similar privileges to American citizens.[1]

Stone Claims: On Government Land:

Lands which are chiefly valuable for building stone are subject to location under the provisions of the law relating to placer claims.

On State Land:

Land which is chiefly valuable for building stone found on state land may be leased from the State Land Commissioners upon a royalty basis only. (See page 56.)

LOCATION OF LODE CLAIMS.

Following are the various steps from the time of discovery to that of applying for patent:

1. Discovery of mineral.
2. Posting Notice of Location.
3. Establishing corners within thirty days.
4. Performing discovery work within sixty days.
5. Filing certificate of location within sixty days.
6. Performing annual assessment work.
7. Applying for patent after $500 has been expended for development work.

Valid Location:

Before making a mineral location, the locator should first ascertain whether or not the land is mineral land on the public domain of the United States, or on State land; second, should discover whether or not the land is open to location, and third, should make a discovery of mineral before posting the location notice.

Discovery:

By discovery of a lode location is meant the finding and locating of a vein, lode, or ledge of rock in place, bearing gold, silver, cinnabar, lead, tin, copper, or other valuable minerals. When the land is unclassified, the discovery of a vein, lode, or ledge has to be of such character that the land, in the opinion of the locator, will prove more valuable for mining than for any other purposes. A discovery of mineral such as gold or other valuable mineral deposits, is also necessary in making a placer location.

"To constitute a valid discovery upon a lode mining claim, three elements are necessary: (1) There must be a vein or lode of quartz or other rock in place; (2) The quartz or other rock in place must carry gold or some other valuable mineral deposit; and (3) the two preced-

[1]See Page 38 for Leasing Act.

ing elements when taken together must be such as to warrant a prudent man in the expenditure of time and money to develop a valuable mine". (41-L. D. 320).

Location Notice: What it should contain—

After making the discovery it is necessary for a locator to post a Notice of Location which can be in a written or printed form, containing (a) name of the claim, (b) name of locator or locators, (c) the date of location, which shall be the date of posting the notice, (d) and the approximate dimensions of the area of the claim intended to be appropriated.

Many prospectors or locators have the opinion that it is absolutely necessary to obtain a printed form for a Notice of Location. This need not be the case as the laws of the State of Montana specify that the notice may be written or printed.

Following are several forms of notices of location that comply with the requirements of the State of Montana:

NOTICE OF LOCATION.

Notice is hereby given that the undersigned locator..... ha..... discovered a vein, lode, or ledge of rock in place, bearing gold, silver, cinnabar, lead, tin, copper, or other valuable minerals; that the same is hereby located and claimed under the provisions of the laws of the United States and the State of Montana, and that said discovery is at or near where this Notice of Location is posted.

The name of the claim is the ..... Lode Mining Claim, and is situated in the County of ....., State of Montana.

The approximate dimensions of area of the claim hereby appropriated are as follows: ..... feet in a ..... direction and .....feet in a ..... direction along the course of the vein, lode or ledge from the point of discovery, and ..... feet on each side from the center of the vein, lode or ledge; the same being ..... feet wide by ..... feet in length.

This notice of location is dated and was posted on the claim at or near the point of discovery this ..... day of ..... A. D. 192.....

Witnesses: Locators and claimants:

....

....

....

A brief form for Notice of Location which complies with all of the requirements of the State of Montana is as follows:

NOTICE OF LODE LOCATION.

Notice is hereby given that the undersigned ha..... discovered a vein, lode, or ledge of rock in place bearing valuable mineral deposits, and ha..... this ..... day of ....., A. D. 192..... located same as the ..... Lode Mining Claim by posting this location notice at or near the point of discovery.

The approximate dimensions of the area of the claim located are:..... feet in a ..... direction, and ..... feet in a ..... direction along the vein, lode, or ledge from the point of discovery and ..... feet on each side of the middle of the vein or lode.

Locators and claimants:

.....

.....

Posting of Notice of Location:

The Notice of Location must be posted in such a manner that it can be readily seen or found by persons passing. Common methods are to tack the notice in a small box and nail the box to a tree ,or to a post placed in the ground, or second, to place the notice in a tin can which is nailed to some tree or post, or third, to place the notice in a can on a pile or rock, etc. This notice should be posted in all cases at the point of discovery or at least within a few feet of the discovery.

Marking Location on the Ground: How and when—

Within thirty days after posting the Notice of Location, it is necessary to mark the location so that the boundaries can be traced. This is usually accomplished by establishing some form of monument, whether of stone or wood, at each corner of the claim. Whatever kind of monument is used must be marked with the name of the claim and the number of the corner or cardinal point. (Points of compass, i. e. the N. E. corner, the S. W. corner, etc.)

Corners: Kind

The corners of a claim may be (1) a tree at least eight inches in diameter and blazed on four sides; (2) a post at least four inches square by four feet six inches in length, set one foot in the ground, unless solid rock should occur at less depth, in which case the post should be set upon such rock, and surrounded in all cases with a mound of earth or rock at least four feet in diameter and two feet high, (3) a stump four inches square and surrounded by a similar mound, (4) a stone at least six inches square by eighteen inches in length, set two-thirds of its length in the ground with a mound of earth or stone along side at least four feet in diameter and two feet high, or (5) a boulder at least three feet above the natural surface of the ground on the upper side.

The corners may be placed where desired and also on any land previ-

ously located. Until a claim is patented, it is advisable to protect the corners by replacing them if they are destroyed, thus definitely marking the boundaries.

Size of Claims Located: Section 2320, Revised statutes.

"Mining claims upon veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits, heretofore located, shall be governed as to length along the vein or lode by the customs, regulations, and laws in force at the date of their location. A mining claim located after the tenth day of May, eighteen hundred and seventy-two, whether located by one or more persons, may equal, but shall not exceed, one thousand five hundred feet in length along the vein or lode; but no location of a mining claim shall be made until the discovery of the vein or lode within the limits of the claim located. No claim shall extend more than three hundred feet on each side of the middle of the vein at the surface, except where adverse rights existing on the tenth day of May, eighteen hundred and seventy-two, render such limitation necessary. The end lines of each claim shall be parallel to each other."

According to the above section a locator may place his corners so that he shall have fifteen hundred feet along the vein and three hundred feet on each side of the center of the vein at the surface. This is the maximum size of a claim. There are no restrictions as to the minimum size of a claim. An ideal location is shown in figure 1 or figure 2.

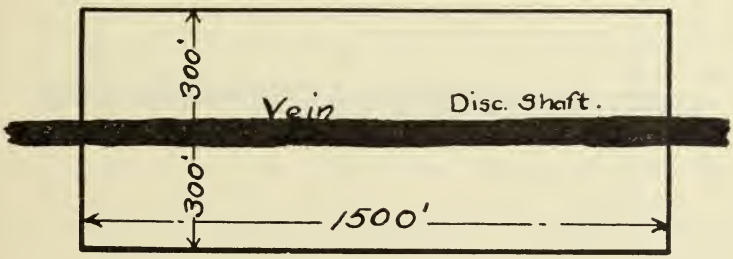

Fig. No. 1.

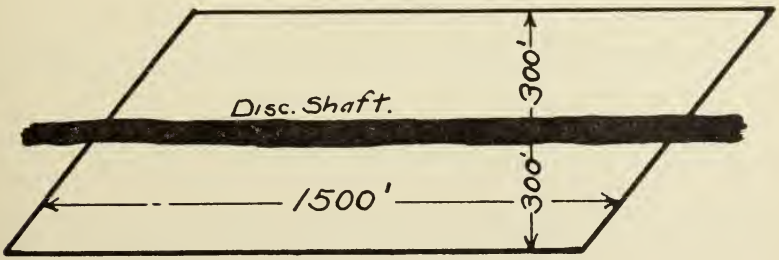

Fig. No. 2.

In figures 1 and 2, the end lines and side lines are parallel. It is not necessary to have the side lines parallel, but no point on a side line may be more than 300 feet from the center of the vein. It is not necessary

for the vein to be equidistant from the side lines, nor is it necessary for the end lines of a location to be parallel. Figure 3 shows a valid location claiming fifteen hundred feet along the vein, with end lines parallel, and side lines three hundred feet or less from the center of the vein.

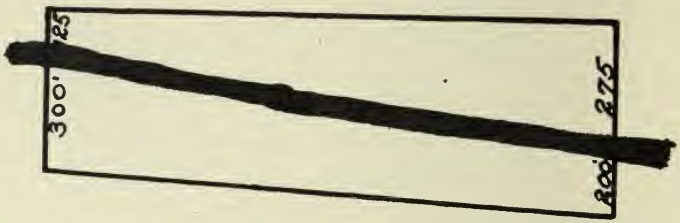

Fig. No. 3.

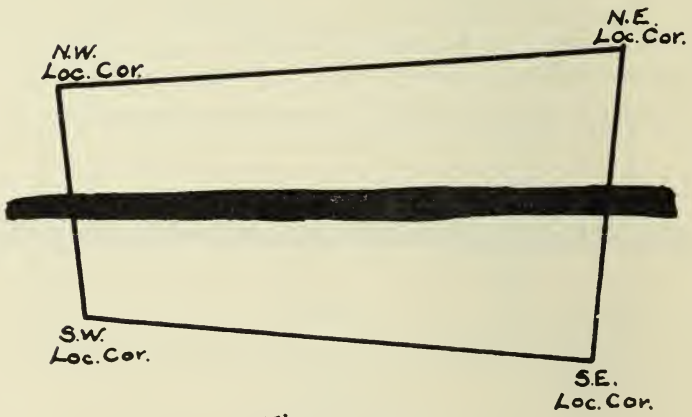

Fig. No. 4.

Figure 4 may be the shape of a valid location but before the same can be patented it will be necessary to make both end lines parallel, and the side lines not more than 300 feet from the center of the vein at any point.

In locating a claim the prospector or locator seldom places his corners so that he has an ideal location, or his end lines parallel, but his rights to prospect and develop such a claim are duly protected if he otherwise complies with the laws of location. A claim is seldom located by making accurate measurements as the distances are usually stepped off. Thus a location is not invalid because its length is slightly greater than 1500 feet or its width more than 300 feet on each side of the middle of the vein, but when making application for patent the dimensions must be corrected accordingly, to comply with government statutes.

It should not be understood from the above statement that a locator

may wilfully stake out a claim with excessive dimensions in order to hold additional land or deprive a third person from making a location. A location that exceeds the maximum size or one with the actual measurements greater than stated in the notice of location is void only as to the excess, and the excess may be located by a third party.

Discovery work on lode claims:

After posting the notice of location, and establishing the corners, a certain amount of work must be performed within a definite period, either by sinking a shaft, or driving a tunnel, or by cuts or trench work. The object of this work is to prevent the appropriation of land for speculative purposes. It is known as Discovery Work and must be performed within sixty days after the date of location.

The discovery shaft, tunnel, cut, etc., must be upon unappropriated ground, and it is necessary that mineral be found in place in the discovery. If a vein or lode is discovered, it is necessary that the apex of the vein or lode shall lie within the boundaries of the location. A location is not valid without a discovery of mineral. The discovery work may be performed at any point along the vein within the boundaries of the location.

Overlapping Locations:

Locations may overlap, and the corners may be placed on another claim, but the discovery work must be performed on ground which does not conflict with any other location, and it must be on unappropriated public domain.

Discovery Shaft:

The discovery work may be performed by sinking a shaft to a depth of at least ten feet vertically below the lowest point of the collar of the shaft, and not less than 150 cubic feet of material must be excavated, and the vein exposed. The Montana law does not state any horizontal dimensions for a discovery shaft.

If the vein is exposed or cut at a less vetrical depth than ten feet, and before 150 cubic feet of material is excavated, the locator may excavate the balance of the material at another point on the claim, but in any case not less than 75 cubic feet of material must be excavated at the point of discovery.

Discovery Cut or Tunnel:

The discovery work may be performed in a cut or tunnel, and in Montana, 150 cubic feet of material must be excavated, and not less than 75 cubic feet must be excavated at the point of discovery. For each location, there must be a discovery, and the required discovery work must be performed on each location.

Certificate of Location:

The State of Montana requires that the notice of location be filed for record with the county clerk and recorder of the county in which the claim is located, within sixty days after location. This record is known as the Certificate of Location, and in order to comply with the laws

of the State it must contain (1) the name of the claim, (2) the name of the locators, (3) the date of the location, (4) a description of the claim with reference to some natural object or permanent monument so as to identify it, (5) the direction and distance claimed along the lode or vein each way from the discovery and the width claimed on each side of the middle of the vein. Certificates of Location must be verified before a Notary Public, or other officer authorized to administer oaths, by the locator or an authorized agent.

Following is a form of Certificate of Location which must be filed with the county clerk of the county in which the claim is situated:

CERTIFICATE OF LOCATION

of the

..... Lode Mining Claim.

Know All Men By These Presents, that the undersigned, on the ..... day of ....., A. D. 19..... did discover a vein or lode, bearing gold, silver, or other valuable metals, and on the same day did locate the same as the ..... Lode Mining Claim, by posting a Notice of Location at the point of discovery, said notice containing the name of the claim, the name.....of the undersigned as locator....., date of location, and approximate dimensions of the claim intended to be appropriated, and that within thirty days after above mentioned date, the undersigned did distinctly mark boundaries of said lode claim by establishing duly marked monuments at each corner of said claim as follows:

Corner No. 1 the [1]..... Corner of this claim is a [2]..... marked [3].....
Corner No. 1 .....Lode.

Corner No. 2 the..... Corner of this claim is a ..... marked .....
Corner No. 2 ..... Lode.

Corner No. 3 the ..... Corner of this claim is a ..... marked .....
Corner No. 3 .....Lode.

Corner No. 4 the ..... Corner of this claim is a ..... marked .....
Corner No. 4 .....Lode.

That within sixty days after the above mentioned date of location the following discovery work was performed [4]..... at which point the vein or lode was discovered, the total excavation amounting to ..... cubic feet.

That the undersigned locator..... claim ..... feet in a .....

[1]NE or NW, etc.
[2]Describe briefly tree, post, boulder, etc.
[3]NE, NW, etc.
[4]Shaft, tunnel, or cut, and dimensions of each.

..... direction and ..... feet in a ..... direction along the course of the vein measured from the point of said discovery and ..... feet on each side of the center of the vein.

That the following references are made to some natural object or permanent monument as will identify the claim:

(1) [5].....

(2) .....

(3) .....

The following claims are adjoining, to-wit:—On the north..... the ..... Lode Mining Claim. On the .....East the .....Lode Mining Claim. On the South..... the .....Lode Mining Claim. On the .....West the .....Lode Mining Claim.

This claim is situated in the ..... Mining District, County of ....., State of Montana.

That the name.... of the locator..... and the claimant..... follow; and the undivided interest in the above described location claimed by each of the undersigned is indicated by the fraction set after each name:

Locators	Interest
.....	.....
.....	.....
.....	.....

Verification of Location Certificate:

STATE OF MONTANA. }
County of..... } ss.

[6].....

being first duly sworn, on oath says: That he is..... the locator..... and claimant..... of the ..... Lode Mining Claim, and that he has read the said Certificate of Location and that the matters and things stated therein are true of his own knowledge.

.....

.....

Subscribed and sworn to before me this ..... day of ..... A. D. 19.....

.....

Notary Public for State of Montana.

Note: Printed forms for Notice of Location and Certificate of Location can be purchased at the different news stands and newspaper offices in the State.

[5]State approx. direction and dist. to some sec., corner, patented mining claim corner, intersection of gulches, permanent peaks, hills, shafts, tunnels, intersection of streams, towns, RR stations etc.

[6]Name of locator or authorized agent, or officer of corporation.

Annual Labor, Representation Work, Assessment Work:

Performing the necessary work of location and discovery, recording the certificate of location, and verifying the same, entitles the locator or claimant to hold the claim until noon of the first day of July succeeding the date of location, but for each period of one year thereafter at least $100.00 must be spent for labor or improvements on the claim.

Example: If a claim is located on March 10, 1922, the first annual work or assessment work must be performed between noon on July 1, 1922 and noon July 1, 1923. If a claim is located on July 10, 1922, the first annual work must be performed during the period from noon July 1, 1923 and noon, July 1, 1924.

Following is an amendment to Act of January 22, 1880.

"That the period within which the work required to be done annually on all unpatented mineral claims located since May 10, 1872, including such claims in Alaska, shall commence at 12 o'clock meridian on the 1st day of July succeeding the date of location of such claim; Provided further, That on all such valid existing claims, the annual period ending December 31, 1921, shall continue to 12 o'clock meridian July 1, 1922." (Approved August 24, 1921.)

Work may begin on the last day of the period within which the annual work must be performed and it must be continued without interruption until completed. Continuous work gives one the right of possession, which until lost, does not make a claim subject to relocation by another person.

Annual Labor on Group of Claims:

When a number of claims are held in common, and are contiguous, the total expenditure that would be necessary to hold all the claims in such a group may be made upon any one claim, provided such work benefits the claims of the entire group. Failure to perform the annual work will subject the claim or claims to relocation unless the locator resumes work before another party locates the same. Locations with only one corner in common are held not to be contiguous.

When Annual Work Ends:

Annual Labor must be performed until the claim is patented or at least until after the issuance of the Register's Certificate. If the Register's Certificate is thereafter cancelled and the annual labor has not been performed, the claim is subject to relocation.

What Will Count as Annual Labor:

The expenditure of $100.00 for annual labor may be for sinking a shaft, driving a tunnel or cross cut, erecting machinery or a building for mining purposes, building of roads, cost of powder, fuse, supplies, or even horse hire when used on the claim for operating a whim or pulling cars. A watchman's service may count for annual labor where the improvements on a claim are valuable. Machinery, boilers, and supplies, brought on the claim, and then removed or not used will not count as a part of the annual labor.

Affidavit of Annual Labor: Time for same—

The State of Montana does not require a locator to make an affidavit as to the annual labor or work performed, but the law states that the owner of the lode or placer claim who performs, or causes to be performed, the annual work or improvement in order to prevent forfeiture of the same, may within twenty days after the annual labor file with the county clerk an affidavit of his own, or of one of the persons who performed the work. This affidavit is accepted by courts as prima facia evidence that the work has been performed.

Co-owners:

When there is more than one locator each must contribute his share of the required amount spent for annual labor but when one of the locators or co-owners fails or refuses to contribute his share, his interest may become forfeited.

Forfeiture of Co-owners Interest: "Advertising Out"

Upon the failure of any one of several co-owners to contribute his share of the required expenditures, the co-owners who have performed the labor or made the improvements as required, may, at the expiration of the year, notify the delinquent co-owner in writing or notice by publication in a newspaper, published nearest the claim, for at least once a week for ninety days; and if, upon the expiration of ninety days after such notice in writing, or upon the expiration of one hundred eighty days after the first newspaper publication and notice, the delinquent co-owner shall have failed to contribute his proportion to meet such expenditures or improvements, his interest in the claim by law passes to his co-owners who have made the necessary expenditures. When a locator or claimant alleges ownership of a forfeited interest, under the above provisions, the sworn statement of the publisher as to the facts of publication, giving dates and a printed copy of the notice published, should be furnished and the claimant must swear that the delinquent co-owner failed to contribute his proper share within the period fixed by the statutes.[1]

Forfeiture:

In order to hold a mining claim of any kind in the State it is necessary to comply with the requirements of the law in regard to (1) making a discovery, (2) posting the location notice, (3) establishing the monuments at the corners, (4) performing the discovery work, (5) recording the certificate of location and verifying the same, (6) and performing the annual assessment or representation work. If any one of the above mentioned requirements are neglected or not complied with, the locator or claimant may lose or may forfeit his rights to the claim provided that another locator has taken up the said claim after the expiration of the time allowed for any one of the above mentioned requirements.

A forfeited claim is subject to relocation, but a forfeiture is not complete until another party has located the said claim. A locator who did

[1]Land Office Regulations.

not comply with the requirements of the law within the period so stated, but who at some later date, possibly several months thereafter, did complete the necessary work before there were any adverse rights, remains the rightful owner of the claim, and his title to the same dates back to the time of location.

Forfeiture does not apply when an owner is forceably prevented from performing his annual labor.

Abandonment:

Abandonment is a voluntary act on the part of a locator or locators relinquishing his, or their, rights to the claim, that is, with the intention of deserting the claim and thus allowing other parties to relocate and work the said claim peacefully. An abandoned claim is subject to immediate relocation.

If the owner encourages another party to locate the claim or states before witnesses that he intends to leave the claim with the intention of not returning, it is an abandonment.

Amended Location:

A locator may, at any time, amend his location, and make any change in the boundaries which does not involve a change in the point of discovery as shown by the discovery shaft. An "Amended Location Notice" must be posted at the original point of discovery the corners must be marked "amended" in addition to the previous markings, and an amended certificate of location conforming to the requirements of an original certificate, must be properly filed and verified.

A defect in a recorded certificate of location may be secured by filing an amended certificate of location.

No additional discovery work need be performed to hold an amended location, thus differing from a relocation.

Relocation:

Any claim which has been forfeited or abandoned may be relocated, and the laws pertaining to a location must be complied with as though it were an original location. (See Location of Lode Claim, Page 12).

For each relocation there must be a discovery although the original discovery point may be adopted, and the original discovery shaft sunk until 150 cubic feet of material is excavated, or the discovered tunnel can be advanced the required amount. The same points may be used for the corners and the same corners may be used after being remarked. A locator or claimant may relocate his own claim for any purpose except to avoid the performance of the annual labor, or he may relocate his own claim and change the boundaries or the point of discovery, or both, but he must comply otherwise with all requirements of the law in regard to an original location.

If for some reason a locator made a valid location but did not perform the necessary annual work within the time so specified, the claim is subject to relocation by another party, but where the time has expired for doing the required annual work, and the original locator again

intends to work the claim, and does actually resume work, it is not necessary to relocate his claim to hold the same, provided that the rights of other parties have not intervened.

Patenting a Lode Claim:

The annual labor or assessment work must be performed each year, unless by a special act of Congress the same is eliminated, this being the case for several years during the recent war. In order to avoid the annual work or in order to secure title from the government, it is necessary to patent one's claim. Patent may be applied for after at least $500.00 has been spent on the claim, or when, for a group of claims, at least $500.00 has been spent on each claim in the group, or the equivalent of $500.00 for each claim in the group may be spent upon any one of the claims so desired, in which case the work must be so performed that all the claims in the group will be developed thereby.

As the services of the U. S. Mineral Surveyor will be required, it is advisable for a locator or claimant to seek his advice or the advice of an attorney as soon as the patent is desired. All official surveys of mining claims, in application for patent, are executed by U. S. Mineral Surveyors who are appointed by the United States Surveyor General for the State.

Only Citizens May Secure Patent

It is absolutely necessary that a claimant be a citizen of the United States, or one who has declared his intention to become such, before patent will be granted by the Government.

How to Obtain Patent:

An application for an order of survey is made by the claimant or his attorney to the Surveyor General of the State in which the claim or claims are located. The application may include the name of the Mineral Surveyor whom the claimant desires to make the necessary survey. The Mineral Surveyor named in the application must have no interest whatsoever in the claim or claims to be surveyed. The application must be accompanied by the location notice, or by a certified copy of the Certificate of Location, obtained from the County Clerk and Recorder of the county in which the claim is situated, and by the sum of $30.00 for office expenses in the Surveyor General's Office. When a group of claims is to be surveyed for patent, the sum of $30.00 for the first claim, and $20.00 for each additional claim is required for office expenses.

The Surveyor General will then issue an order for the survey naming therein the Mineral Surveyor. The order is sent direct to the Mineral Surveyor who in turn makes the necessary surveys as prescribed in the Manual of Instructions for the Survey of Mineral Lands.

A Mineral Surveyor cannot act as an attorney and a Mineral Surveyor at the same time. After the survey is completed, and the necessary returns forwarded to the Surveyor General, including reports, plat, and field notes, it is checked, and if approved, the Surveyor is so notified, and his duty in connection with the survey thereby ceases.

One plat and one copy of the original field notes are prepared by the Surveyor General. The plat is sent to the General Land Office where ten lithographic copies are made from the original. One copy is given to the claimant for posting on the claim together with a notice of intention to apply for patent; seven copies and the original field notes are retained by the Surveyor General; one copy, and a copy of the field notes are sent to the claimant to be filed by him with the Register of the Land Office to be finally transmitted by that officer, with other papers in the case, to the General Land Office; and one copy is to be sent by the Surveyor General to the Register of the proper land district, to be retained on his files for future reference. Copies of all plats beginning with Survey No. 9200 may be purchased from the Surveyor General for fifty cents each.

The claimant must post a copy of the plat, with a notice of intention to apply for patent, on the claim before filing his application for patent. At least two disinterested witneses must sign an affidavit that the notice and plat have been posted on the claim. After the application for patent has been published for a period of sixty days, and after the necessary plats, notes, and affidavits, have been properly posted and filed, and upon payment of five dollars per acre for lode claims, and two dollars and fifty cents for placer claims, a register's certificate will be issued to the applicant, provided, that no contests are filed against the claim and fraud has not been committed.

Following is Section 2325 of the Revised Statutes, regarding the patenting of mineral lands:

"A patent for any land claimed and located for valuable deposits may be obtained in the following manner: Any person, association, or corporation authorized to locate a claim under this chapter, having claimed and located a piece of land for such purposes, who has, or have, complied with the terms of this chapter, may file in the proper land office an application for a patent under oath, showing such compliance, together with a plat and field notes of the claim or claims in common, made by or under the direction of the United States surveyor-general, showing accurately the boundaries of the claim or claims, which shall be distinctly marked by monuments on the ground, and shall post a copy of such plat, together with a notice of such application for a patent, in a conspicuous place on the land embraced in such plat previous to the filing of the application for a patent, and shall file an affidavit of at least two persons that such notice has been duly posted, and shall file a copy of the notice in such land office, and shall thereupon be entitled to a patent for the land, in the manner following: The register of the land office, upon the filing of such application, plat, field notes, notices, and affidavits, shall publish a notice that such application has been made, for the period of sixty days, in a newspaper to be by him designated as published nearest to such claim; and he shall also post such notice in his office for the same period. The claimant at the time of filing this application, or at any time thereafter, within the sixty days of publication, shall file with the register a certificate of the United States surveyor-general that five hundred dollars' worth of labor has been expended or improvements made upon the claim by himself or grantors; that the plat is correct, with such further description by such reference to natural objects or permanent monuments as shall identify the claim, and furnish an accurate description, to be incorporated in the patent. At the expiration of the sixty days of publication, the claimant shall file his affidavit, showing that the plat and notice have been posted in a conspicuous place on the claim during such period of publication. If

no adverse claim shall have been filed with the register and the receiver of the proper land office at the expiration of sixty days of publication, it shall be assumed that the applicant is entitled to a patent, upon the payment to the proper officer of five dollars per acre, and that no adverse claim exists; and thereafter no objection from third parties to the issuance of a patent shall be heard, except it be shown that the applicant has failed to comply with the terms of this chapter. This section was amended January 22, 1880, as follows:"

When Made by Authorized Agent:

"That section twenty-three hundred and twenty-five of the Revised Statutes of the United States be amended by adding thereto the following words: 'Provided, that where the claimant for a patent is not a resident of or within the land district wherein the vein, lode, ledge, or deposit sought to be patented is located, the application for patent and the affidavits required to be made in this section by the claimant for such patent may be made by his, her, or its authorized agent, where said agent is conversant with the facts sought to be established by said affidavits: And Provided, That this section shall apply to all applications now pending for patents to mineral lands.' "

Form for Application to U. S. Surveyor General for Surveys of Mining Claims:

.....

....., 19....

United States Surveyor-General,

Sir: ....., claimant.... hereby make.... application for an official survey, under the provisions of Chapter 6, Title 32, of the Revised Statutes of the United States, and regulations and instructions thereunder, of the mining claim known as the....., situated in..... mining district, ... county..... in section....., township No. ....., Range No..... Said claim is based upon a valid location made on ....., 19....., and duly recorded on ....., 19....., and is fully described in the duly certified copy of the record of the location certificate, filed herewith. Said certificate contains the name of the locator, the date of location, and such a definite description of the claim by reference to natural objects or permanent monuments as will identify the claim, and said location has been distinctly marked by monuments on the ground, so that its boundaries can be readily traced. ..... request that you send.....an estimate of the amount required to defray the expenses of platting and other work in your office, required under the regulations, that ..... may make proper deposit therefore, and that thereupon you will cause the survey to be made by ....., United States mineral surveyor, and proper action to be taken thereon by your office, as required by the United States mining laws and regulations thereunder.

....., Claimant.

P. O. Address.....

.....County.

.....

Adverse Claim: Section 2326 Revised Statutes.

"Where an adverse claim is filed during the period of publication, it shall be upon oath of the person or persons making the same, and shall show the nature, boundaries, and extent of such adverse claim, and all proceedings, except the publication of notice and making and filing of the affidavit thereof, shall be stayed until the controversy shall have been settled or decided by a court of competent jurisdiction, or the adverse claim waived. It shall be the duty of the adverse claimant, within thirty days after filing his claim, to commence proceedings in a court of competent jurisdiction, to determine the question of the right of possession, and prosecute the same with reasonable diligence to final judgment; and a failure so to do shall be a waiver of his adverse claim. After such judgment shall have been rendered, the party entitled to the possession of the claim, or any portion thereof, may without giving further notice, file a certified copy of the judgment roll with the register of the land office, together with the certificates of the surveyor-general that the requisite amount of labor has been expended or improvements made thereon, and the description required in other cases, and shall pay to the receiver five dollars per acre for his claim, together with the proper fees, whereupon the whole proceedings and the judgment roll shall be certified by the register to the Commissioner of the General Land Office, and a patent shall issue thereon for the claim, or such portion thereof as the applicant shall appear, from the decision of the court, to rightly possess. If it appears from the decision of the court that several parties are entitled to separate and different portions of the claim, each party may pay for his portion of the claim with the proper fees, and file the certificate and description by the surveyor-general, whereupon the register shall certify the proceedings and judgment roll to the Commissioner of the General Land Office, as in the preceding case, and patents shall issue to the several parties according to their respective rights. Nothing herein contained shall be construed to prevent the alienation of a title conveyed by a patent for a mining claim to any person whatever."

This section was amended by Act of March 3, 1881, as follows:

"That if, in any action brought pursuant to section twenty-three hundred and twenty-six of the Revised Statutes, title to the ground in controversy shall not be established by eithey party, the jury shall so find, and judgment shall be entered according to the verdict. In such case costs shall not be allowed to either party, and the claimant shall not proceed in the land office or be entitled to a patent for the ground in controversy until he shall have perfected his title."

This section was further amended by Act of April 26, 1882, as follows:

"That the adverse claim required by section twenty-three hundred and twenty-six of the Revised Statutes may be verified by the oath of any duly authorized agent or attorney in fact of the adverse claimant cognizant of the facts stated; and the adverse claimant, if residing at the time being beyond the limits of the district wherein the claim is situated, may make oath to the adverse claim before the clerk of any court of record of the United States or the State or Territory where the adverse claimant may then be, or before any notary public of such State or Territory."

When there is any dispute over the rights of possession of the land it is necessary for the adverse claimant to file his adverse claim during the sixty day period of publication, and commence proceedings to determine the question of rights of possession within thirty days thereafter, but if no adverse claim is filed before the time for publication expires, application is then made for title to the ground, such application being accompanied by a sum equivalent to $5.00 per acre or fraction thereof for lode claims, and $2.50 per acre or fraction thereof for placer claims,

for which the Register will issue a duplicate receipt. The returns of the survey with the required approval of the Surveyor-General are then furnished to the Commissioner of the General Land Office in Washington, D. C., who upon approving the application, will issue the patent, which is a conveyance from the United States Government.

After the purchase price of the land has been accepted by the Land Office, for which a Register's certificate has been issued, no annual work need be performed.

After obtaining patent the owner may sell, transfer, or otherwise dispose of said claim or claims in any manner desired. Upon receiving title from the Government the patentee is granted the exclusive right of possession and enjoyment of all the surface included within his claim, and of all veins, lodes, and ledges throughout their entire depth, the top or apex of which lies inside of his surface boundaries, and he may follow such veins, lodes, or ledges, downward indefinitely even though it may be necessary to pass outside of the vertical boundaries of his side lines. Such rights as granted by the Government, can only apply to such portions of the veins that lie between vertical planes passing through the end lines of the claim which must be parallel. These vertical planes are indefinite in size. (See Section 2322, Revised Statutes, page 29).

Such rights are known as "Extralateral Rights" and due to the many varied opinions and complications pertaining to the same it would not be proper nor possible to discuss the same, even briefly, within the limits of this bulletin.

Following are sketches illustrating what has been said above.

Figure 5 shows an ideal claim with two veins dipping in the same direction and figure 6 shows a section through AA in which an end view is seen.

The owner according to Section 2322, of the Revised Statutes, owns both veins, and can follow each, indefinitely in depth, beyond the vertical plane of the side lines passing through the corners 1 and 4 as shown in figure 5. The owner's rights to follow and mine the vein beyond the side

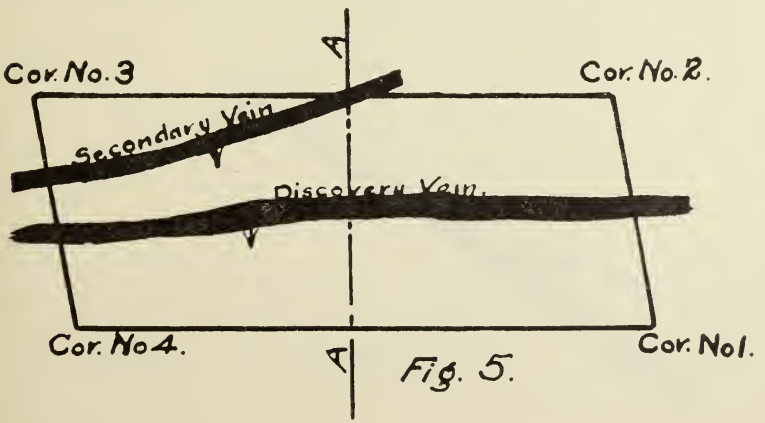

Fig. 5.

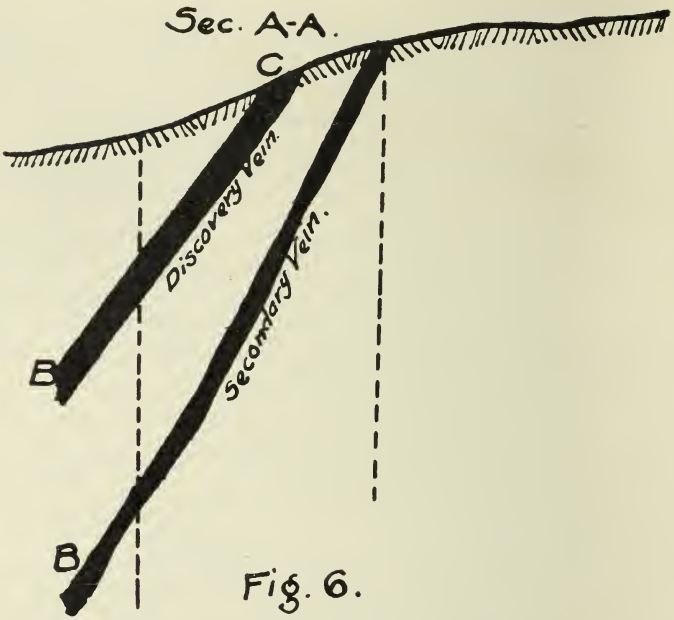

Fig. 6.

lines as at B in figure 6, are known as "Extraside Rights" or "Extralateral Rights." "C," figure 6, is the apex or top of the vein. In order to have any "Extralateral Rights" it is necessary to have the top or apex of the vein within the limits of one's claim, and the vein passing through at least one end line.

Apex should not be confused with outcrop as the latter may or may not be the apex. See figure 7.

AA is an outcrop, that is, where the vein comes to the surface, while "B" is the apex and an outcrop.

An outcrop is the exposed edge of the vein at the surface.

The apex of a vein is the top edge of the vein along its entire course. It may appear at the surface, or in the case of a blind vein, it may be at a considerable distance from the surface.

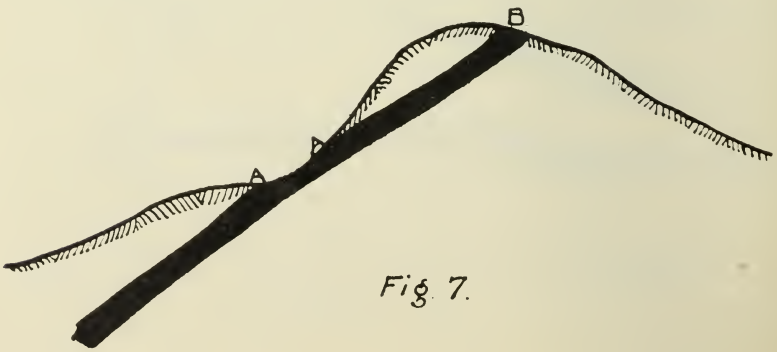

Fig. 7.

Fig. 8.

In figure 8, the outcrop is shown at D and the apex at E.

The claimant may by his extralateral rights, mine all ore in the main vein (figure 5) between the two vetrical parallel planes passing through the end lines 1-2 and 3-4, and all ore from the secondary vein between two parallel vertical planes passing through corners 3-4 and the point where the secondary veins crosses the side lines 2-3.

Revised Statutes Pertaining to Rights of Possession and Extralateral Rights:

"Sec. 2322. The locators of all mining locations heretofore made, or which shall hereafter be made, or any mineral vein, lode, or ledge, situated on the public domain, their heirs and assigns, where no adverse claim exists on the tenth day of May, eighteen hundred and seventy-two, so long as they comply with the laws of the United States governing their possessory title, shall have the exclusive right of possession and enjoyment of all the surface included within the lines of their locations, and of all veins, lodes, and ledges throughout their entire depth, the top or apex of which lies inside of such surface lines extended downward vertically, although such veins, lodes, or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical planes drawn downward as above described, through the end lines of their location, so continued in their own direction that such planes will intersect such exterior parts of such veins or ledges. And nothing in this section shall authorize the locator or possessor of a vein or lode which extends in its downward course beyond the vertical lines of his claim to enter upon the surface of a claim owned or possessed by another."

"Sec. 2336 R. S. Where two or more veins intersect or cross each other, priority of title shall govern, and such prior location shall be entitled to all ore or mineral contained within the space of intersection; but the subsequent location shall have the right of way through the space of intersection for the purposes of the convenient working of the mine. And where two or more veins unite, the oldest and prior location shall take the vein below the point of union, including all the space of intersection.—Act of May 10, 1872."

PLACER LOCATIONS.

A placer claim, that is, a claim containing mineral deposits in a loose state or not in place, may be located in the same manner as a lode claim. See page 12. Mineral deposits which may be located as placer deposits are mentioned on page 10.

The area of one location may vary from twenty acres to one hundred and sixty acres, depending upon the number of locators. A corporation

or any qualified locator may not locate more than twenty acres in one location. A claim containing one hundred and sixty acres may be located by an association of eight locators.

One discovery of mineral is necessary for each location, whether it is a location of twenty acres by an individual or one of one hundred and sixty acres by an association of persons. A location having an area in excess of that allowed by the law, is void only as to the excess.

In Montana it is necessary to make a discovery, post a notice of location, erect corners, perform the discovery work, record the certificate of location, and perform the necessary annual labor for placer claims in the same manner as for lode claims.

The following are the sections of the Revised Statutes of the United States relating to placers:

Section 2329, Revised Statutes: "Claims usually 'called 'placers' including all forms of deposit, excepting veins of quartz, or other rock in place, shall be subject to entry and patent, under like circumstances and conditions, and upon similar proceedings, as are provided for vein or lode claims; but where the lands have been previously surveyed by the United States, the entry in its exterior limits shall conform to the legal subdivision of the public lands." (Act of July 9, 1870).

Section 2330. "Legal subdivisions of forty acres may be subdivided into ten-acre tracts; and two or more persons, or associations of persons, having contiguous claims of any size, although such claims may be less than ten acres each, may make joint entry thereof; but no location of a placer claim, made after the ninth day of July, eighteen hundred and seventy, shall exceed one hundred and sixty acres for any one person or association of persons, which location shall conform to the United States surveys; and nothing in this section contained shall defeat or impair any bona fide preemption or homestead claim upon agricultural lands, or authorize the sale of the improvements of any bona fide settler to any purchases."

Section 2331. "Where placer claims are upon surveyed lands, and conform to legal subdivisions, no further survey or plat shall be required, and all placer-mining claims located after the tenth day of May, eighteen hundred and seventy-two, shall conform as near as practicable with the United States system of public-lands surveys, and the rectangular subdivisions of such surveys, and no such location shall include more than twenty acres for each individual claimant; but where placer claims cannot be conformed to legal subdivisions, survey and plat shall be made as on unsurveyed lands; and where by segregation of mineral lands in any legal subdivision a quantity of agricultural land less than forty acres remains, such fractional portion of agricultural land may be entered by any party qualified by law, for homestead or preemption purposes." (Act of May 10, 1872).

A placer claim must be rectangular or square in shape, and it must conform to the subdivisions of the public land, that is, the boundaries must run as nearly as practicable, north and south, or east and west whether on surveyed or unsurveyed land.

No location may exceed twenty acres for one locator. A location greater than twenty acres but not in excess of forty acres must be made by two locators, one greater than sixty acres but not in excess of eighty acres must be made by four locators, and so on.

"Gulch Placers" may be located with the boundaries somewhat irregular, but if possible, the boundaries should run north and south, and east and west, as stated above.

All locations should be compact and regular in form. Long narrow locations or one grossly irregular will not be permitted.

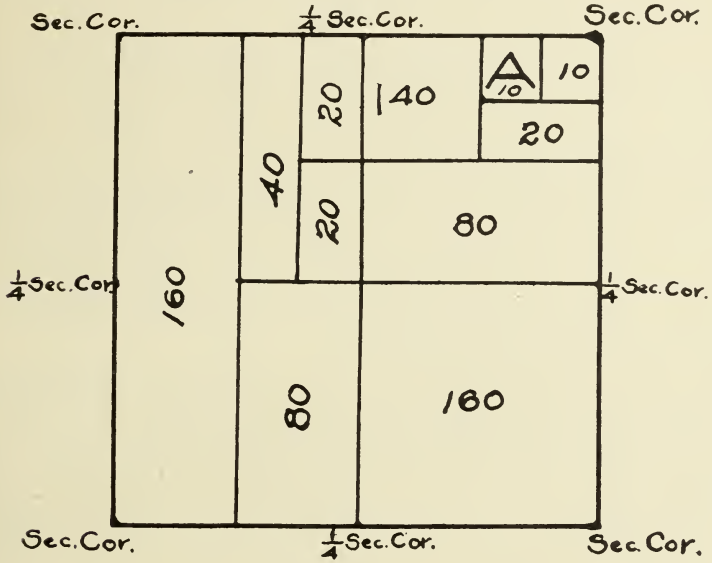

Fig. 9.

Figure 9 illustrates how public lands may be subdivided in order to take up various tracts as placer claims.

Form for Placer Location:

NOTICE OF PLACER LOCATION.

Notice is hereby given that the undersigned locator.... and claimant.... ha..... on this.....day of....., A. D. 19..... discovered a deposit of gold, or other valuable deposits, having a commercial value, and do..... hereby locate and claim same, which shall be known as ..... Placer Mining Claim, and did on the same day post this notice at the point of discovery.

The dimensions of this claim are ..... feet in a ..... direction, and ..... feet in a ..... direction from the point of discovery, by ..... feet on each side of middle of claim, containing ..... acres.

Witnesses: Locators and claimants:

.....

.....

.....

Note: For each multiple of twenty acres in the located area or claim, there should be one qualified locator who must sign the notice of location.

This notice of location must be posted on the claim at or near the point of discovery.

Form for Certificate of Placer Location:

CERTIFICATE OF LOCATION

of the

..... Placer Mining Claim.

Know All Men by These Presents, That the undersigned, each of whom is a citizen of the United States, or has declared his intention to become such, did, on the.....day of....., 19....., discover a placer deposit bearing gold, ... and other minerals having a commercial value, and on the same day did locate and claim the same as the.....Placer Mining Claim, by posting a notice of location conspicuously at the point of said discovery, containing the name of said claim, the name.... of the undersigned as locator...., the date of said location, and the approximate dimensions of such claim intended to be appropriated.

This claim is situated in.....Mining District (unorganized), in the County of....., State of Montana. The adjoining claims are as follows, to-wit:

On the North....., the.....Claim;

On the .....East, the.....Claim;

On the South....., the.....Claim;

On the .....West, the.....Claim;

Measured from the discovery..... of this claim as a starting point, the following natural objects and permanent monuments are distant as follows, to-wit: ..... is distant..... feet in a..... direction; .... is distant ..... feet in a.....direction.

Subsequent to the date of said location, to-wit, on the.....day of ....., 19....., the undersigned did distinctly mark said location on the ground so that its boundaries could be readily traced, in the following manner, to-wit:

Beginning at.....Corner No. 1, which is a.....

.....

.....

.....

and which is distant..... feet in a .....

direction from the point of discovery, and running thence

First Course: Direction,....., distance.....feet,

to.....Corner No, 2, which is a.....

.....

.....

.....

..... and running thence

Second Course: Direction, ..., distance.....feet,

to.....Corner No. 3, which is a.....

.....

.....

.....

..... and running thence

Third Course: Direction,....., distance.....feet,

to.....Corner No. 4, which is a.....

.....

.....

.....

..... and running thence

Fourth Course: Direction,....., distance.....feet;

.....

.....

.....

.....

.....

to Corner No. 1, the place of beginning.

Within sixty days after posting said notice of location the undersigned performed the following discovery work, to-wit:

At the point of discovery dug a.....of the following dimensions, to-wit:.....

.....

.....

.....

constituting in all.....cubic feet of excavation, and said work has disclosed at the point of discovery a valuable deposit of.....

.....

.....

.....

.....

.....

.....

The undivided interest in the above described location, claimed by each of the undersigned, is indicated by the fraction set after each name.

....

....

....

Locator.... and Claimant.....

STATE OF MONTANA, }
County of..... } ss.

.....being duly sworn on oath says: That....he....is.....the locator.... and claimant.... whose name.....signed to the foregoing

Certificate of Location; that ....he....has.....read the said Certificate, and knows the contents thereof, and that the matters and things therein stated are true of his own knowledge.

.....

Subscribed and sworn to, before me this.....day of..... A. D., 19.....

.....

Notary Public in and for.....County, State of Montana.

The locators or claimants according to the state laws of Montana, may at their option set forth in the certificate of location a description of the discovery work, the corner monuments and markings thereon, and any other facts showing a compliance with the provision of the law. The certificate of location must be verified as in the case of a lode claim by some one of the locators or by an authorized agent. (See page 17).

Discovery Work and Annual Labor:

The same amount of discovery work is required for a placer claim as a lode claim, that is, the excavation of at least 150 cubic feet of material in which the mineral deposit has been disclosed. (See Lode Claim, Page 17).

The annual labor, which is the same as a lode claim must be performed in order to hold the placer location whether it be for a location of twenty acres or for a location by an association of eight locators for one hundred sixty acres.

Patenting Placer Claim:

A patent for a placer claim may be applied for in the same manner as a lode claim. (See Section 2325, Revised Statutes. Page 24.)

Vein or Lode Within Placer Claim:

"Sec. 2333. Where the same person, association, or corporation is in possession of a placer claim, and also a vein or lode included within the boundaries thereof, application shall be made for a patent for the placer claim, with the statement that it includes such vein or lode, and in such case a patent shall issue for the placer claim, subject to the provisions of this chapter, including such vein or lode, upon the payment of five dollars per acre for such vein or lode claim and twenty-five feet of surface on each side thereof. The remainder of the placer claim, or any placer claim not embracing any vein or lode claim shall be paid for at the rate of two dollars and fifty cents per acre, together with all costs of proceedings; and where a vein or lode, such as described in section twenty-three hundred and twenty, is known to exist within the boundaries of a placer claim which does not include an application for the vein or lode claim shall be construed as a conclusive declaration that the claimant of the placer claim has no right of possession of the vein or lode claim; but where the existence of the vein or lode in a placer claim is not known, a patent for the placer claim shall convey all valuable mineral and other deposits within the boundaries thereof."

No person may legally prospect for a vein or lode, or locate a vein, if discovered, within the boundaries of a valid placer location without the consent of the placer claimant.

If a vein is discovered within the boundaries of a valid placer location by the placer claimant it will not be necessary to locate the vein as a

regular lode location, but when an application is made for a patent for the placer claim, the fact that the vein or lode exists within its boundaries should be stated, and an application for a patent for the vein or lode should then be included with the placer application. If a vein is known to exist, and it is not so stated in the application, the placer claimant will have no rights to the vein. The title to a vein found after the placer patent is issued, remains with the owner of the claim. No extralateral rights are granted for such a vein.

When a valuable vein is discovered within the lines of a placer location before an application is made for patent, it would be advisable for the placer claimant to locate the vein by making a regular lode location covering a tract twenty-five feet on each side of the vein, and not to exceed fifteen hundred feet in length, in order to avoid any possible future disputes. When such a vein is properly located and patented, extralateral rights are granted, otherwise no extralateral rights are attached to veins found within the placer location.

Placer claims must be paid for at the rate of two dollars and fifty cents per acre or fraction thereof provided they do not contain any veins or lodes. In case of a known vein the regular price of five dollars per acre for a strip of ground twenty-five feet on each side of the vein is required.

When forty-acre tracts are subdivided into ten-acre tracts, they must be in square form, and with the boundaries of the tracts running north and south, and east and west. Entry for such ten-acre tracts may be made after the usual proceedings without any additional surveys or plats, when on surveyed government land.

A tract of ten acres, as in "A," figure 9, page 31, may be described as the N. W. ¼ of the N. E. ¼ of the N. E. ¼ of the section in which the claim is located.

Forfeiture, Abandonment, Relocation, Co-Owners of Placer Claims:

The rules relating to forfeiture, abandonment, relocation, and rights of co-owners apply in the same manner for placer locations as for lode locations. (See pages 21 and 22).

Tunnel Claims: Location.

(See Section 2323, Revised Statutes, page 10).

After a tunnel has been started and enters cover, a location notice for the tunnel is required to be posted at or near the mouth of the tunnel. This notice should contain (1) the name or names of the locator or locators claiming the tunnel right, (2) the course and direction of the proposed tunnel, (3) the height and width of the tunnel and (4) the course and distance from the face to some natural and permanent objects in the vicinity. When the notice is posted, the claimant should establish the boundary lines by stakes or monuments placed along such lines at proper interval, and extending to the end of the proposed tunnel, that is, 3,000 feet from the first working face. These lines are so staked that there will exist definite boundaries within which prospecting or locating

of any previously unknown veins or lodes is prohibited while work on the tunnel is being prosecuted with reasonable diligence. (L. O. Reg.).

A copy of the tunnel location notice must be filed with the County Clerk and Recorder, to which notice must be attached a sworn statement or declaration of the owners, claimants, or projectors of such tunnel, setting forth the facts in the case; stating the amount expended by themselves and their predecessors in interest in prosecuting the work thereon; the extent of the work performed, and that it is bona fide their intention to prosecute work on the tunnel so located and described with reasonable diligence for the development of a vein or lode or for the discovery of mines, or both. This notice of location must be duly recorded, and, with the said sworn statement attached, kept on the Recorder's files for future reference.

Work must be performed in the tunnel with reasonable diligence. If the work in the tunnel is not performed for a period of six months, the right to all undiscovered veins on the line of the tunnel shall be considered as abandoned, and other locators may stake out lode claims on the surface which may contain such undiscovered veins.

The laws of Montana do not make known any requirements in regard to the location of a tunnel claim and the foregoing have been taken from Land Office Regulations.

No Patent for Tunnel Claim:

A tunnel claim cannot be patented, but all veins or lodes that are cut while driving the tunnel may be located by staking out the boundaries of a lode claim as prescribed by the laws for a regular lode location, and such lode claims may then be patented in the usual way. Money spent in driving the tunnel may be counted as annual labor in making application for patent for such lode claims as include the veins and lodes as cut by the tunnel.

Labor on Tunnel Claim:

By an Act of Congress, approved February 11, 1875, Section 2324, of the Revised Statutes, was amended, so that where a person or company has driven a tunnel for the purpose of developing a lode or lodes, the money so expended in the tunnel shall be taken and considered as expended on such lode or lodes, and that the owner or claimant shall not be required to perform any work on the surface of such lode or lodes in order to hold the same as required by laws pertaining to annual labor. (See page 20).

Staking Lode Claims on Surface:

The method for locating or staking out a lode claim which includes such vein or lode as cut by a tunnel right seems to have provoked many different opinions. The laws of location do not state any definite point as to where the location corners, or the discovery on any claim should be; that is, a location is not void if the discovery point is near one end line, or in the center of the claim, or even close to some corner, and it would therefore seem logical and valid to locate a claim on either

side of the tunnel for a distance of 1500 feet along the vein and in any direction, the distance to be measured in all cases from the tunnel, or to locate 1500 feet along such vein or lode so that a portion of the claim may lie on either side of the tunnel.

Millsites: Location of (See page 11).

Millsite claims may be located and recorded in the same manner as other claims except that no discovery work is required. When a millsite is located in connection with a lode claim, the certificate of location shall describe by appropriate reference such lode claims. (See location of Lode Claims, page 12).

Form for Millsite Location:

NOTICE OF MILLSITE LOCATION.

Notice is hereby given, that the undersigned claimant.... and owner.... of the.....Lode Claim, or.....Quartz Mill or Reduction Works, situated in the County of....., State of Montana, did, on this.....day of.....A. D. 19....., locate five acres of non-mineral land as the.....Millsite.

That, the approximate dimensions of area are..... feet by.....feet.

That this notice was posted on the same date at the..... Corner No. 1, from which the.....Corner No. 2 is approximately .....feet in a.....direction, thence..... feet in a.....direction to.....Corner No. 3, thence.....feet in a.....direction to..... Corner No. 4, thence.....feet in a.....direction to the place of beginning.

Witnesses: Locators and claimants:

....

....

....

A certificate of location and a verification of the same must be filed with the County Clerk and Recorder of the County in which the millsite is located and must comply with all the requirements necessary in filing for a lode claim. (See page 18).

The millsite may be used in connection with the lode claims appurtenant thereto. It must be used for the erection of a mill, houses for workmen, warehouses, or other mining and milling purposes. No annual labor need be performed on a millsite.

Patenting Millsites:

An application for patent to a millsite may be included in the application for patent for the lode claim appurtenant thereto.

An application for patent to a millsite may also be made by an owner of a quartz mill or other reduction plant provided he does not own a

lode claim. He may make an application in the same manner as for a mining claim, and receive patent by paying $5.00 per acre or fraction thereof but there must be no adverse rights.

Millsite for Owner of Patented Claims:

The owner of a patented lode claim may, by an independent application, secure a millsite if good faith is shown in its use or occupation in connection with the lode and no adverse claim exists.[1]

[1]Land Office Regulations.

Timber and Timber Lands:

By an Act of Congress, approved June 3, 1878, permission was granted to all persons who are residents of Montana, to cut and remove, for building, agricultural, mining, or other domestic purposes, any timber or other trees growing or being on the public lands, which were mineral and not subject to entry under existing laws of the United States, except for mineral entry, subject to such rules and regulations as the Secretary of the Interior may prescribe for the protection of the timber, etc. The above provisions do not extend to railroad corporations.

Timber may be cut on unpatented mining claims and used in connection with the same. Timber on patented claims may be cut and used as the owner sees fit.

Timber may be cut and used for mining purposes by a locator or claimant of a valid location on a forest reserve, and timber may also be cut and removed from a forest reservation by obtaining permission from the local forest ranger or supervisor and paying stumpage for the timber.

The Act of June 4, 1897, provides that: "The Secretary of the Interior may permit, under regulations to be prescribed by him, the use of timber and stone found upon such reservations, free of charge, by bona fide settlers, miners, residents, and prospectors for minerals, for fire wood, fencing, building, mining, prospecting, and other domestic purposes as may be needed by such persons for such purposes; such timber to be used within the state or territory respectively where such reservations may be located."

LEASING ACT.

Coal, Phosphate, Oil, Oil Shale, Gas, Sodium.

The Leasing Act as approved by Congress on February 25, 1920, is an act which relates to the mining and prospecting of mineral deposits of coal, phosphate, oil, oil shale, gas and sodium.

Lands Affected:

Any land containing such deposits as mentioned above, and owned by the Government, including those in National Forests, and lands entered or patented with such deposits reserved under laws to the United States, but excluding (1) land acquired under the act known as the "Appalachain Act," as approved March 1, 1911, and (2) those in National Parks, and (3) lands withdrawn or reserved for Military or Naval uses or purposes,

and (4) any land patented without such mineral deposits reserved to the United States, and (5) Indian Reservations, are affected by the passage of this act.

Title to Such Lands: Permit and Lease:

Title to such deposits on any Government lands cannot be obtained. A permit must be obtained from the Secretary of the Interior to prospect Government lands for such deposits, and a lease must be obtained to mine the deposits after the same have been found.

Who May Receive a Permit or Lease:

Only citizens of the United States, association of citizens, or any corporation, organized under the laws of the United States, or of any state or territory, may obtain permits or leases.

Cities or municipalities may obtain a permit to prospect for coal, oil, oil shale, or gas, or a lease to mine coal, oil, oil shale, or gas, but not for phosphate or sodium.

Aliens:

Aliens or citizens of another country may not own any interest by stock ownership, stock holding, or stock control, in any lease acquired under the Leasing Act unless his country grants similar or like privileges to citizens or corporations of the United States. An alien may not obtain a direct holding of a lease. Under certain conditions, American corporations, with alien stockholders, may obtain a lease.

Number of Leases Allowed:

Only one coal, phosphate, or sodium lease may be held during the life of such lease in any state, by any person, association, or corporation.

Only three gas or oil leases in any one state, and not more than one lease within the geologic structure of the same producing oil or gas field can be held by any one person, association, or corporation.

Only one oil shale lease can be obtained by any person, association, or corporation.

Unlawful Rights of Persons or Corporations:

A corporation may not hold an interest in more than the maximum number of leases, either by direct holding as a lessee, or indirectly as a stockholder in other corporations holding leases.

A corporation holding the maximum number of leases, for any kind of the above mentioned mineral deposits, may not hold any interest in any other association, or corporation having similar leases.

A person with a direct holding of a lease of any kind may hold an interest as a member of an association, or as a stockholder of a corporation holding a similar lease if the combined area embraced in the direct holding of a lease, and the area covered by other interests, does not exceed the maximum number of acres allowed for the respective kinds of mineral for any one lessee. Thus an individual may hold stock in any number of corporations holding oil or gas leases, provided his stock interests do

not represent a greater acreage than 2,560 acres in the same producing structure, or 7,680 acres in the same state. An individual may hold three leases directly for oil or gas, and one lease for coal, sodium, phosphate, or oil shale, and, at the same time hold a stock interest in a corporation having leases, provided his direct and indirect holdings do not exceed the maximum area for one person.

Any interests which are illegally held shall be forfeited to the United States by proceedings in the United States District Courts.

Interests Acquired by Descent, Will, Judgment, Etc.:

Any interest acquired by descent, will, judgment, or decree may be held for two years after its acquisition.

Lawful Combined Interests for Pipe Lines—Railroad:

Any number of lessees may combine their interests for the purpose of constructing and operating a refinery, or constructing and operating a common pipe line, or railroad, to be operated and used by them jointly in the transportation of oil from their wells, or from the wells of other lessees, or in the transportation of coal, provided application is made to the Secretary of the Interior, and permission is granted to combine such interests.

Unlawful Combined Interests:

Any land or deposits leased by any lessee which may be controlled by any unlawful trusts or combinations by the consent of the lessee, or any agreement made to control prices or output, or control an excessive area as provided, shall be forfeited by regular court proceedings.

Cancellation of Prospecting Permits:

Permits to prospect any government land may be cancelled by the Secretary of the Interior if the prospecting work is not carried on in a diligent manner, and according to the terms and conditions stated in the permit.

Application for Permits or Leases:

Application for permits, addressed to the Commissioner of the General Office, should be filed in the local land office for the district in which the lands or deposits desired for prospecting or leasing, are situated.

Permits and Leases on Land Patented With Mineral Rights Reserved:

When the surface rights have been disposed of by the government and the mineral rights reserved, a preference right for a prospecting permit or a lease in case of discovery, will be granted to the holder of such surface rights as stated under the various headings for each particular deposit.

A prospecting permit or lease which shall apply to all deposits of coal, phosphate, oil, oil shale, gas, or sodium, may be granted to any qualified person, association, subject to such conditions as are or may later be provided.

Right of Way for Pipe Lines:

Any qualified applicant will be granted a right of way through the public lands or forest reserves for a pipe line for the transportation of oil or natural gas, provided that the pipe line shall be constructed, operated and maintained as a common carrier. The right of way shall be for the tract of ground occupied by the pipe and 25 feet on each side, under such regulations as to the survey, location, application, and the use, as may be prescribed by the Secretary of the Interior.

Every lease of oil land shall provide that the lessee, assignee, or beneficiary, if owner, or operator, or owner of a controlling interest in a pipe line, or of any company operating the same, shall at reasonable rates and without discrimination convey the oil of the Government, or of any citizen or company not the owner of a pipe line, operating a lease or purchasing oil or gas as provided in the Leasing Act. If the above provisions are not complied with, a grant for a pipe line right of way will be forfeited.

Right of Way Over Lands Held Under Permit or Lease:

The Secretary of the Interior reserves the right to permit upon just terms, such easements, or rights of way, over any land, or through any tunnels, on any lands leased, occupied, or even subject to lease or occupation, as may be necessary to prospect or work any deposits described in the Leasing Act and likewise for the shipment and treatment of material produced.

Reserving of Surface Rights of Lands Leased:

The Secretary of the Interior may reserve as much of the surface rights in any one lease as will not be necessary for the use of the lessee in prospecting or working the deposit, and may lease, sell, or otherwise dispose of the same. When any surface rights are reserved by the Secretary of the Interior, such reservations must be stated in the lease.

Assigning, Sub-Leasing:

No lease shall be assigned or sub-let except with the consent of the Secretary of the Interior.

Relinquishment of Lease:

The lessee may, in the judgment of the Secretary of the Interior, be permitted to make a written relinquishment of all rights to a lease and if accepted shall be released of all further obligations. A lessee may also surrender any portion of the area in a lease which may be described by legal subdivisions.

Methods for Working Deposits:

Each lease shall contain the following provisions, provided that the provisions do not conflict with the laws of the state in which the leased land is situated:

1. Skill and care in the operation of the property.
2. Safety and welfare of miners.
3. Prevention of undue waste.

4. Working day of 8 hours for underground miners except in case of emergency.
5. Non-employment of any boy under sixteen years of age, or of any female without regard to age, in any mining operations below the surface.
6. Regulations to insure the fair and just weighing or measurement of coal mined by each miner.
7. Complete freedom of purchase for all workmen.
8. Payment of wages at least twice a month.
9. Sale of production to the United States and to the public at reasonable prices.
10. Protection of the interests of the United States.
11. Prevention of monopoly.
12. Safe-guarding of the public welfare.

COAL LANDS.

Permit and Lease:

A permit may be obtained from the Secretary of the Interior by any qualified applicant including municipalities, to prospect on government land for coal, or to explore such deposits, or to determine if the coal can be mined at a profit.

Such permits will be granted for a period of two years for a tract of land not exceeding 2,560 acres (4 sections).

Discovery of Coal by the Permittee—Lease:

If coal is discovered by any qualified permittee within the two-year period, and can be mined in commercial quantities, a lease will be granted without competitive bidding by the Secretary of the Interior for all or any part of the land included in the permit. The application for a lease should be filed in the proper district land office before the expiration of the period of the permit.

Railroads:

A company or corporation operating a common carrier railroad may hold a permit or lease for coal deposits, provided the coal is for its own use for railroad purposes. Such company or corporation may not hold more than one permit or lease for each 200 miles of its road, operated by steam within the state in which the coal deposits are located. Spurs, switches, and branch lines built to connect the leased area with the railroad, shall not be included in the above mileage.

Areas Leased:

Coal lands will be divided into 40-acre tracts or multiples thereof by the Secretary of the Interior upon the petition of any qualified applicant for a lease, but no tract will be leased which contains more than 2,560 acres (4 sections).

Method of Leasing:

Leases may be obtained by competitive bidding or by any other method adopted by the Secretary of the Interior, provided that a notice of such

lease has been given for 30 days in a newspaper in the county in which the land, or coal deposits are situated.

Application for Leases for Land Occupied and Improved:

The Secretary of the Interior is authorized in awarding leases to consider, and recognize equitable rights of persons who, prior to February 25, 1920, have improved, occupied, or claimed the lands offered for leasing.

Leasing Additional Land.

When a deposit held under any valid lease shall be worked out in three years, the Secretary of the Interior may lease to the lessee an additional tract of land or coal deposits, upon the same conditions as the original lease, but the combined area of the unworked deposits in the original lease, and the area of the additional lease must not exceed 2,560 acres.

Consolidation of Leases:

A number of lessees may surrender their original leases, and then consolidate their leases by including in a new lease such areas, not to exceed 2,560 acres of adjoining land, provided the same is approved by the Secretary of the Interior.

Non-contiguous Land:

The Secretary of the Interior may allow a single lease for non-contiguous coal land not exceeding 2,560 acres, which may be operated as a single lease.

Royalties and Rentals:

The amount of royalty will be specified in the lease but it will not be less than five cents per ton of 2,000 pounds mined. An annual rental must also be paid in advance. Such rental will be specified in the lease, and will not be less than twenty-five cents per acre for the first year, fifty cents an acre for the second, third, fourth, and fifth years, and not less than one dollar per acre for each year thereafter during the period of the lease.

All rentals for any year will be credited against the royalties as they accumulate for that year.

Period of Lease:

A lease may be granted for intermediate periods provided the deposits are worked continuously and in a diligent manner, except when interrupted by strikes or other causes not attributal to the lessee. At the end of twenty years the Secretary of the Interior may make any changes in the terms and conditions of the lease as he determines, unless provided otherwise by law. The Secretary of the Interior may permit the suspension of operations under such lease for a period not to exceed six months at any one time when market conditions are such that the mine cannot operate except at a loss.

License to Cities and Individuals for Domestic Purposes:

Cities may obtain a limited license or permit from the Secretary of the Interior for the purpose of mining coal and disposing of the same

to the residents of the city for household use. The land is to be selected within the same state in which the city is located. The amount of land allowed in a permit is as follows: Not more than 320 acres for a city having less than 100,000 population, and not more than 1,280 acres for a city having 100,000 to 150,000 population, and not more than 2,560 acres for a city having a population greater than 150,000. When such a limited license or permit is granted, no royalty or rental is charged provided the coal is sold to the residents without profit. When a limited license or permit is held by a city, it will in no way interfere with a regular lease held by the city for coal land as provided in the Leasing Act.

Individuals or associations of individuals may obtain a limited license or permit to prospect, mine, and take coal from public lands for their own use without the payment of royalty or rental. Under no conditions may coal mined under such a limited license be sold.

A corporation may not obtain a limited license or permit.

PHOSPHATE LANDS.

Government land containing deposits of phosphate may be leased by the Secretary of the Interior to any qualified person through advertisement, competitive bidding, or any other method that he may adopt.

Size of Lease—Shape:

No lease may be obtained for more than 2,560 acres (4 sections) which must be described by legal subdivision when on surveyed land. All leased land must be in compact form and its length must not be more than two and one-half times its width.

Lease on Unsurveyed Land:

If a lease is applied for on unsurveyed land, the land will be surveyed by the Government at the expense of the applicant, in accordance with the rules and regulations prescribed by the Secretary of the Interior, and the lands leased must conform to legal subdivisions.

Royalties and Rentals:

All royalties shall be specified in the lease by the Secretary of the Interior, but in no case shall they be less than two per cent of the gross value of the output of phosphates or phosphate rock at the mine.

An annual rental, payable in advance, shall be fixed by the Secretary of the Interior but in no case shall it be less than 25 cents per acre for the first year, 50 cents per acre for the second, third, fourth and fifth years, and $1.00 per acre for each and every year thereafter during the life of the lease. Such rentals shall be credited against the royalties for that year.

Period of Lease:

Leases shall be for an intermediate period upon condition of a minimum annual production, except where strikes, not attributable to the lessee, interfere with the operation.

At the end of each 20-year period the Secretary of the Interior may make any readjustments of terms and conditions as he finds necessary, unless otherwise provided by law at the end of such periods.

Suspension of Operations:

The Secretary of the Interior may permit the suspension of operations for a period not exceeding twelve months at any one time when market conditions are such that work cannot be continued except at a loss to the lessee.

Additional Lands:

Any lessee may obtain a permit for additional surface rights not to exceed 40 acres of unappropriated land for the purpose of prospecting, development, extraction, treatment, and removal of such phosphate deposits.

OIL AND GAS LANDS.

Permit for Unappropriated Lands:

A permit to prospect for oil and gas may be obtained from the Secretary of the Interior by any qualified applicant for a period not exceeding two years upon a tract of unappropriated government land not exceeding 2,560 acres.

No Permits for Land in Known Oil or Gas Field:

No permit will be granted for land within any known geological structure of a producing oil or gas field.

Location of Lands:

Any land for which a permit shall be applied for must be located in a compact form according to legal subdivisions, if surveyed, and in approximately square or rectangular form if on unsurveyed land, the length of which must not be more than two and one-half times its width. In contiguous tracts may be located under certain conditions due to prior locations. All locations must be made before filing an application for a permit.

Preference Right to a Permit:

Any applicant shall be entitled to a preference right to a permit for a period of thirty days, after erecting a monument not less than four feet high and not less than four inches square or in diameter, at some conspicuous place on the land located, and after posting a proper notice in writing on or near such monument. Such notice must contain the date, and hour of posting, name of applicant, a description of the land to be covered by the permit by reference to courses and distances from the monument and from any other natural object and permanent monuments as will identify the land, stating the area in acres thereof, and also stating that an application for a permit will be made within thirty days after posting such notice.

Terms and Conditions of Permit:

Within 90 days after receiving permit, the corners of the land included in the permit must be marked with substantial monuments and a notice,

stating that a permit has been granted and giving also, a description of the land included in the permit, must be posted at some conspicuous place.

Work Required:

Drilling operations must begin within six months from the date of permit.

Within one year, one or more wells, not less than six inches in diameter, must be drilled to a depth of not less than 500 feet each, unless valuable deposits of oil are discovered at less depth.

Within two years one or more wells to a depth of not less than 2,000 feet must be drilled unless valuable deposits are sooner discovered.

A permit may be extended for a period of two years by the Secretary of the Interior when the permittee has not been able to prospect the ground properly.

Location of Wells:

No wells may be drilled for oil or gas within 200 feet of the outer boundaries of the land covered by a permit or lease, unless the adjoining lands have been patented or title otherwise held by private owners.

Precautions when Drilling:

A permit shall be granted only upon the conditions that all necessary precautions will be taken to prevent the waste of any oil or gas developed in the land, and to prevent any water from entering the wells drilled, which may in any way cause or injure the oil or gas deposits. A permit shall be forfeited if the above precautions are not observed while drilling.

Extension of Life of Permit:

If the permittee is unable, with the exercise of diligence, to test the land within two years, an application for an extension of time, not to exceed two years may be filed during the period of the permit. Reasons must be given for applying for such extension of time.

Discovery of Oil or Gas:

When oil or gas is discovered on lands covered by a valid permit, the permittee shall be entitled to lease one-fourth of the land held under the permit, or in any case, the permittee shall be entitled to lease 160 acres if there are that many acres within the permit.

The permittee shall also be entitled to a preference right to lease the remainder of the land covered by his prospective permit, but the same may be obtained only by competitive bidding, or by any other method prescribed by the Secretary of the Interior.

Royalty Before Applying for Lease:

The royalty on all oil or gas produced upon lands held by a permit will be twenty per cent of the gross value until such time as the permittee makes application for a lease for the one-quarter of the permit area.

Description of Land Selected for Lease:

All lands selected for leasing must be in compact form and described by legal subdivision of the public land surveys.

When tracts are selected on unsurveyed land they shall be surveyed by the government in proper manner and at the expense of the applicant for a lease.

Life of Lease:

Leases shall be for periods of twenty years and the lessee may also have a preference right to renew his lease for periods of ten years upon terms prescribed by the Secretary of the Interior.

Royalties and Rental upon Leased Land:

The royalty charged upon leased lands included in the one-fourth of the original permit will be five per cent in amount of oil or gas, or in actual value of the production.

The royalties in all other leases for oil or gas shall be determined by competitive bidding, or by other methods as perscribed by the Secretary of the Interior, but shall not be less than twelve and one-half per cent in amount or value of production.

The annual rental for all leases for oil or gas lands shall be one dollar per acre, payable in advance, and the rental paid will be credited against the royalties as they accumulate for that year.

Reduction of Royalty:

Whenever the average daily production of any oil well does not exceed ten barrels the Secretary of the Interior is authorized to reduce the royalty on future production, provided that the wells cannot be successfully operated upon the royalties fixed in the lease The royalty upon any gas lease will likewise be reduced when the production decreases so that the well cannot be operated except at a loss.

Leasing of Land in a Producing Oil or Gas Field:

All land or deposits within the known geological structure of a producing oil or gas field may be leased to the highest qualified bidder for an area not exceeding six hundred and forty acres. Such area shall not exceed in length two and one-half times its width.

The royalty on such deposits will not be less than twelve and one-half per cent in amount or value of production, and the annual rental not less than one dollar per acre.

Preference Right of Owner of Surface:

A preference right to a permit and to a lease in case of discovery, will be granted to any one who has entered, or patented an agricultural tract with the mineral rights reserved, provided the land was not withdrawn or classified as oil or gas land at the time of entry. A like permit and lease will be granted to an assignee where the assignment was made prior to January 1, 1918. Such a permit or lease will not be granted on lands included in any railroad grant.

A joint application for a permit not to exceed 2,560 acres may be made by the holders of such lands within an area not greater than a township (36 sections). The royalty and conditions of a lease, in case of discovery will be the same as stated before.

Application by Other Persons:

An application for a permit for entered or patented lands, where the oil and gas has been reserved may be filed by a person other than the entryman or owner of the land, provided that the applicant serve personal notice of such application upon the owner or owners of the land. Upon receiving such notice, the owner of the land must file an application within thirty days in the proper local land office, if he desires to exercise his preference right, if any, to a permit for such land. The preference right applicant must furnish evidence that personal notice was served on the owner, and that the party served is the owner of the land involved.

Government to Extract Helium from Gas:

The Government reserves the right to extract helium from all gas produced from land permitted, leased, or otherwise granted under the provisions of the Leasing Act.

OIL SHALE LANDS

The Secretary of the Interior is authorized to lease any deposits of oil shale belonging to the United States to any qualified person or corporation, and under such rules and regulations as he may prescribe.

Size of Lease:

No lease shall be granted for an area exceeding 5,120 acres (8 sections) which must be described by legal subdivision. When the land is unsurveyed it will be surveyed by the government, but at the expense of the applicant for lease.

Period of Lease:

A lease will be granted for indeterminate periods upon such conditions as the Secretary of the Interior may include, relative to the methods of mining, development, and prevention of waste.

Royalties and Rental:

The royalty charged for an oil shale lease will be specified in the lease, and the annual rental, payable at the beginning of each year, will be fifty cents per acre. The rental paid will be credited against the royalties. The royalties may be readjusted at the end of each twenty year period.

In order to encourage production of petroleum products, the payment of the annual rental and royalty may be waived by the Secretary of the Interior for the first five years of such lease.

Claims Held Under Former Laws:

Any person having a valid claim under existing laws of January 1, 1919, and who relinquishes the same to the United States, will be entitled to a lease for such area of the land relinquished as shall not exceed 5,120 acres (8 sections).

Anyone who has been found guilty of fraud, or who has knowledge of fraud, or who has been dishonest shall not be entitled to such a lease.

Only one lease shall be granted to any person, association or corporation.

SODIUM LANDS

Permit:

A permit to prospect for deposits containing sodium as chlorides, sulphates, carbonates, borates, silicates, or nitrates, for a period of two years, shall be granted to any applicant for an area not to exceed 2,560 acres, in a reasonably compact form, by legal subdivision if surveyed; if unsurveyed by metes and bounds description.

Lease:

If a valuable discovery of such deposits is made within two years, the permittee shall be entitled to a lease for one-half of the land included in the permit, but not to exceed 1,200 acres according to legal subdivisions. If the land containing such deposits is unsurveyed, it will be surveyed by the government at the expense of the permittee. The permittee has also a preference right to lease the remaining one-half of the land included in his permit.

Royalty:

The lands shall be leased at a royalty of not less than twelve and one-half per cent of the amount or value of the production.

Known Deposits of Sodium:

Lands known to contain deposits of sodium and not held by permits or leases, may be leased through the Secretary of the Interior by advertisement, competitive bidding, or as he may adopt, and in any area not to exceed 2,560 acres.

Rental:

The annual rental shall be paid in advance at a rate of fifty cents per acre for the first calendar year or fraction thereof, and one dollar per acre per annum thereafter. Rentals shall be credited against the royalties for each year.

Period of Lease:

Leases shall be for indeterminate periods subject to readjustment at the end of each twenty year period.

Additional Lands:

An additional forty-acre tract of unoccupied, non-mineral land may be rented to a permittee or a lessee of sodium deposits at the rate of twenty-five cents per acre, for camp sites, refining works, and other purposes connected with and necessary to the proper development and the use of the deposits covered by the permit or lease.

MINING LAWS OF MONTANA

REVISED CODES OF 1921.

Location and Record of Mining and Millsite Claims.

Section 7365. Discovery-Notice Marking Boundaries-Sinking Shaft.
" 7366. Record of Certifiacte of Location.
" 7367. Placer Locations Heretofore Made, Effect of.
" 7368. Annual Work-Affidavit-Contents-Record.
" 7369. Millsites.
" 7370. Relocation of Abandoned Claim.
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" 7378. Effect of Patent.
" 7379. Amended Locations.
" 7380. Effect of Amended or Additional Declaratory Statement.
" 7381. Location of Mining Claims on State Land.
" 7382. Owners of Mines Have Right-of-way.
" 7383. Right-of-way for Road or Ditch.
" 7384. Proceedings to Obtain Right-of-way.

Section 7365. Discovery—Notice—Marking—Boundaries—Sinking Shaft. Any person who discovers, upon the public domain of the United States, within the State of Montana, a vein, lode or ledge of rock in place, bearing gold, silver, cinnabar, lead, tin, copper or other valuable deposits, or a placer deposit of gold, or other deposit of minerals having a commercial value which is subject to entry and patent under the mining laws of the United States, may, if qualified by the laws of the United States, locate a mining claim upon such vein, lode, ledge or deposit, in the following manner, viz.:

I. He shall post, conspicuously, at the point of discovery a written or printed notice of location, containing the name of the claim, the name of the locator (or locators, if there be more than one), the date of the location, which shall be the date of posting such notice, and the approximate dimensions of area of the claim intended to be appropriated.

II. Within thirty days after posting the notice of location, he shall distinctly mark the location on the ground so that its boundaries can be readily traced. It shall be prima facie evidence that the location is properly marked if the boundaries are defined by a monument at each corner or angle of the claim, consisting of any one of the following kinds:

(1) A tree at least eight inches in diameter, and blazed on four sides. (2) A post at least four inches square by four feet six inches in length, set one foot in the ground, unless solid rock should occur at a less depth, in which case the post should be set upon such rock, and surrounded in all cases by a mound of earth or stone at least four feet in diameter by two feet in height. A squared stump, of the requisite size, surrounded by such mound, shall be deemed the equivalent of a post and mound. (3) A stone at least six inches square by eighteen inches in length, set two-thirds of its length in the ground, with a mound of earth or stone alongside at least four feet in diameter by two feet in height, or (4) a boulder at least there feet above the natural surface of the ground on the upper side.

Where other monuments, or monuments of lesser dimensions than those above described, are used, it shall be a question for the jury, or for the court where the action is tried without a jury, as to whether the location has been marked upon the ground so that its boundaries can be readily traced. Whatever monument is used, it must be marked with the name of the claim and the designation of the corner, either by number or cardinal point.

III. Within sixty days after posting such notice, he shall sink a shaft upon the vein, lode or deposit, at or near the point of discovery, to be known as the discovery shaft. Such shaft shall be sunk to the depth of at least ten feet, vertically, below the lowest part of the rim of such shaft at the surface, or deeper if necessary to disclose the vein or deposit located, and the cubical contents of such shaft shall be not less than one hundred and fifty cubic feet; provided, that any cut or tunnel which discloses the vein, lode or deposit located at a vertical depth of at least ten feet below the natural surface of the ground and which constitutes at least one hundred and fifty cubic feet of excavation, shall be deemed the equivalent of such shaft, and, provided also, that, where the vein, lode or deposit located is disclosed at a less vertical depth than ten feet, any deficiency in the depth of the discovery shaft, cut or tunnel may be compensated for by any horizontal extension of such working, or by any excavation done elsewhere upon the claim, equaling, in cubical contents, the cubical extent of such deficiency; but in every case at least seventy-five cubic feet of excavation shall be made at the point of discovery.

Section 7366. **Record of Certificate of Location.**—Within sixty days after posting the notice of location and for the purpose of constituting constructive notice of the location, the locator shall record his location in the office of the County Clerk of the county in which such mining claim is situated. Such record shall consist of a certificate of location containing:

1. The name of the lode or claim.

2. The name of the locator or locators, if there be more than one.

3. The date of location, and such description of said claim, with reference to some natural object or permanent monuments, as will identify the claim.

IV. In the case of a lode claim, the direction and distance claimed along the course of the vein each way from the discovery shaft, cut or tunnel, with the width claimed on each side of the center of the vein.

V. In the case of a placer claim, the dimensions or area of the claim, and the location thereon of the discovery shaft, cut or tunnel.

VI. The locator and claimant, at his option, may also set forth, in such certificate of location, a description of the discovery work, the corner monuments and the markings thereon, and any other facts showing a compliance with the provisions of this law.

Such certificate of location must be verified, before some officer authorized to administer oaths, by the locator, or one of the locators, if there be more than one, or by authorized agent. In the case of a corporation, the verification may be made by any officer thereof, or by an authorized agent. When the verification is made by an agent, the fact of the agency shall be stated in the affidavit.

A certificate of location so verified, or a certified copy thereof, is prima facie evidence of all facts properly recited therein.

Section 7367. **Placer Locations Heretofore Made—Effect of.** All placer mining locations or locations of valuable mineral deposits, which have heretofore been recorded in the office of the County Clerk or Recorder, have the same force and effect as though such records had been authorized by law, except in cases where the rights of third persons had been acquired before the passage of this code; and such record is entitled to be admitted in evidence in any court.

Section 7368. **Annual Work—Affidavit—Contents—Record.** The owner of a lode or placer claim who performs or causes to be performed the annual work or makes the improvements required by the laws of the United States, in order to prevent the forfeiture of the claim, may, within twenty days after the annual work, file in the office of the county clerk of the county in which such claim is situated an affidavit of his own, or an affidavit of the person who performed such work or made the improvements, showing:

1. The name of the mining claim, and where situated.

2. The number of days work done, and the character and value of the improvements placed thereon;

3. The date of performing such work, and of making the improvements;

4. At whose instance the work was done or the improvements made;

5. The actual amount paid for work and improvements, and by whom paid when the same was not done by the owner.

Such affidavits, or a certified copy thereof, are prima facie evidence of the facts therein stated.

Section 7369. **Mill Sites.** Mill site claims may be located and recorded in the same manner as other claims, except that no discovery or discovery work is required. Where a mill site claim is appurtenant to a mining claim, the certificate of location of such mill site claim shall describe, by appropriate reference, the mining claim to which it is appurtenant.

Section 7370. **Relocation of Abandoned Claim.** The relocator of an abandoned or forfeited mining claim may adopt as his discovery any shaft or other working, existing upon such claim at the date of the relocation,

in which the vein, lode or deposit is disclosed, but, in such shaft or other working, he shall perform the same discovery work as is required in the case of an original location.

Section 7371. **Rights of Relocator.** The rights of a relocator of any abandoned or forfeited mining claim, hereafter relocated, shall date from the posting of his notice of location thereon, and, while he is duly performing the acts required by law to perfect his location, his rights shall not be affected by any re-entry or resumption of work by the former locator or claimant.

Section 7372. **Amended Location.** A locator or claimant may at any time, amend his location and make any change in the boundaries which does not involve a change in the point of discovery as shown by the discovery shaft by marking the location as amended upon the ground, and filing an amended certificate of location conforming to the requirements of an original certificate of location. A defect in a recorded certificate of location may be cured by filing an amended certificate.

Section 7373. **Relocation by Owner.** A locator or claimant may, at any time, re-locate his own claim for any purpose, except to avoid the performance of annual labor thereof, and, by such re-location, may change the boundaries of his claim, or the point of discovery, or both, but such relocation must comply, in all respects, with the requirements of this law as to an original location.

Section 7374. **Amendment or Relocation Not a Waiver of Acquired Rights.** Where a locator or claimant amends or relocates his own claim, such amendment or re-location shall not be construed as a waiver of any right or title acquired by him by virtue of the previous location or record thereof, except as to such portions of the previous location as may be omitted from the boundaries of the claim as amended or re-located.

As to the portion of ground included both in the original location and the location as amended or relocated, he may rely either upon the original location or the location as amended or re-located, or upon both. Provided, that nothing herein contained shall be construed as permitting the locator or claimant to hold a tract which does not include a valid discovery.

Section 7375. **Rights of Third Persons not Affected.** No amendment or re-location of a mining claim by the locator or claimant thereof shall interfere with the right of any third person existing at the time of such amendment or re-location.

Section 7376. **Validating Locations Heretofore Made.** All mining locations, made and recorded under the laws of this State, heretofore in force, that in any respect have failed to conform to the requirements of such laws, shall, nevertheless, in the absence of the rights of third persons accruing prior to the passage of this Act, be valid if the making and recording of such locations conform to the requirements of this Act.

Section 7377. **Defective Locations Good Against Persons With Notice.** The period of time prescribed by this law for the performance of any act, shall not be deemed mandatory where the act is performed before the rights of the third persons have intervened, and no defect in the posted

notice or recorded certificate shall be deemed material, except as against one who has located the same ground, or some portion thereof, in good faith and without notice. Notice to an agent, who makes a location in behalf of another, shall be deemed notice to his principal and notice to one of several co-claimants shall be deemed notice to all.

Section 7378. **Effect of Patent.** The issuance of a United States patent for a mining claim shall be deemed conclusive that the requirements of the laws of this State relative to the location and record of such mining claim have been duly complied with; provided, however, that where questions of priority are involved the date of the location shall be an issuable fact where it is claimed to have been prior to the date of the record of the location.

Section 7379. **Amended Locations.** If at any time the locator of any mining claim heretofore or hereafter located, or his successors or assigns shall apprehend that his original declaratory statement was defective or erroneous, or that the requirements of law had not been complied with, or shall be desirous of changing his boundaries, or taking any part of an overlapping claim which has been abandoned, or in case his original declaratory statement was filed prior to the passage of this law, and he shall be desirous of securing the benefit of this Act, such locator, or his successors or assigns, may file an additional or amended declaratory statement, subject to the provisions of this Act; provided that such relation or filing of an amended or additional declaratory statement shall not interfere with the existing rights of others at the time of such relocation or filing of the amended or additional declaratory statement, and no such relocation or amended or additional declaratory statement, or other record thereof, shall preclude the claimant or claimants from proving any such title as he or they may have held under the previous location and notice thereof.

Section 7380. **Effect of Amended or Additional Declaratory Statement.** Any amended or additional declaratory statement which may have heretofore been filed by a locator, or his successors or assigns, shall have the same force and effect and be subject to the same terms and conditions as though the same had been filed under the provisions of the proceeding section.

Section 7381. **Location of Mining Claims on State Lands.** The location of mining claims upon state land is provided for by sections 1905 and 1906 of the Political Code. (See page 67.)

Section 7382. **Owners of Mines have Right-of-way.** The owner of a mining claim held under the laws of the United States by patent or otherwise, or under the local laws and customs of the state, has a right-of-way over and across the land or mining claim, patented or otherwise, of another, as prescribed in this chapter.

Section 7383. **Right-of-way for Road or Ditch.** Whenever a mine or mining claim is so situated that it cannot be conveniently worked without a road thereto, or a ditch to convey water thereto, or a ditch or cut to convey the water therefrom, or without a flume to carry water and tailings therefrom, or without a shaft or tunnel thereto, which road, ditch,

cut, flume, or tunnel must necessarily pass over, under, through, or across any lands or mining claims owned or occupied by another, such owner is entitled to a right-of-way for said road, ditch, cut, flume, shaft, or tunnel over, under, through, and across the lands or mining claims belonging to another, upon compliance with the provisions of this chapter.

Section 7384. **Proceedings to Obtain Right-of-way.** Whenever such owner desires to work a mine or mining claim, and it is necessary to enable him to do so successfully and conveniently that he should have a right-of-way for any of the purposes mentioned in the foregoing sections; and, if such right-of-way has not been acquired by agreement between him and the owner of the land or claims over, under, across, and upon which he seeks to establish such right-of-way, it is lawful for him to present to the judge of the district court a complaint asking that such right-of-way be awarded to him. The complaint must be verified, and contain a particular description of the character and extent of the right sought, a description of the mine or mining claim of the owner, and the mining claim or claims and the lands to be affected by such right-of-way, with the names of the occupants or owners thereof, and may also set forth any tender or offer hereinafter mentioned.

LOCATION OF MINING CLAIMS ON STATE LANDS.

Section 1905. Location of Mining Claims on State Lands.
Section 1906. Proof of Mineral Character of Land.
Section 1891. Lands Valuable for Stone.

Section 1905. **Location of Mining Claims on State Lands.** Locations of mining claims not exceeding six hundred (600) feet in width and fifteen hundred (1500) feet in length, each, may be made upon lands belonging to the State as follows: The discoverer of a body of mineral in either a vein, lode or ledge, or mineral in a placer deposit, shall immediately post conspicuously a notice that he has made such a discovery, on the date stated in such notice, and shall complete such location in all respects as prescribed by the laws of this State for the location of mining claims upon the public lands of the United States, except that no notice of such location need be recorded in the office of the County Clerk, but such notice shall be filed with the Register of State Lands. Such procedure shall empower the locator to retain possession of and operate said claim for the period of one year, at the end of which time he shall be required to purchase said claim at ten dollars per acre or take a lease thereof at such price, or upon such terms as may be agreed upon between him and the State Board of Land Commissioners.

Section 1906. **Proof of Mineral Character of Land.** Before the locator will be allowed to purchase the claim located by him, satisfactory proof at a hearing, if deemed necessary, must be submitted to the State Board of Land Commissioners, that such claim is more valuable for mineral purposes than for any other purpose, and that the same contains a body of mineral in place, or a placer deposit, of sufficient value to justify the operation of the same as a present fact; provided, that no mining claim shall be located upon any coal or oil lands; and, provided, further, that

all hearings under the provisions of this section shall be had before the contest board with like procedure as other contested cases; and provided, further, that no lands classified under Subdivision 4 of the classification in the constitution shall be sold as mineral lands, but the mineral therein may be sold separately from the surface.

Section 1891. **Lands Valuable for Stone.** Whenever it shall appear to the State Board of Land Commissioners that there is a deposit of stone valuable for building, mining, or other commercial purposes upon any section or subdivision of State land, the Board shall not lease the same for any purpose except for the extraction and working of the stone and then upon a royalty basis only, upon such terms as the Board shall prescribe. The Board may lease the remainder of the section or subdivision for agriculture, grazing or other purposes, as may appear for the best interests of the State, as other State lands are leased; but shall provide in all such cases for a right of way across said State land or any adjoining State land for all purposes connected with the working and disposition of the stone.

SALE, LEASES AND RENTALS OF STATE LANDS.

REVISED CODES 1921.

Section 1846. Coal Lands—What Deemed—Selection.
Section 1852. Sale of State Lands—Reservation of Coal, Oil and Gas.
Section 1882. Leasing of Land.
Section 1883. Lands—How Leased.
Section 1890. Rental of Coal Lands.

Section 1846. **Coal Lands—What Deemed—Selection.** All coal areas in the State after final examination are defined by the United States geological survey, or other authority under the government of the United States, shall be recognized by the authorities of this State as coal lands, until otherwise determined; and no such lands shall be sold, but such lands may be leased by the State to any person or persons, company or corporation, but only on a royalty basis as herein provided; provided, however, that the surface rights of such land may be sold or may be leased for either agricultural or grazing purposes, but any other State lands may be designated as coal lands by the State Board of Land Commissioners, and withdrawn from sale when, in the opinion of the Board, such lands contain coal.

Section 1852. **Sale of State Lands—Reservation of Coal, Oil and Gas.** The State Board of Land Commissioners may direct the sale of any State lands, except as provided in this act, * * * and, provided, further, that all leases and conveyances of State lands by the State Board of Land Commissioners shall contain a reservation to the State of all coal, oil and gas contained therein.

Section 1882. **Leasing of Land.** The State Board of Land Commissioners may lease any portion of the land of the state at a rental to be determined after an examination of the land by an appraiser, except as

herein provided. The lessee shall pay the annual rental in advance to the Register of State Lands, who shall receipt for the same. If stone, coal, coal-oil, gas, or other mineral not mentioned herein, be found upon the state land, such land must be leased only for the purpose of obtaining therefrom the stone, coal, coal-oil, gas, or other mineral, for such length of time, and conditional upon the payment to the register of such royalty upon the product as the State Board of Land Commissioners may determine.

Section 1883. **Lands, How Leased.** At every public sale of state lands, each tract of land, except timber lands, for which no bid for its purchase has been received, shall be immediately offered for lease to the highest bidder, as follows: By quarter-sections, or so much thereof as belongs to the state, in the case of lands classified as agricultural (a); by half-sections, in the case of lands classified as agricultural (b); and by sections in the case of lands classified as grazing; and smaller tracts shall not be leased, unless it is deemed impossible to lease as above described, or unless a larger price may be obtained thereby; and no land shall be leased for a longer period than five years, nor for a less rental than the minimum rental fixed by the board, which shall not be less than five per centum per annum of the appraised value of such lands.

Section 1890. **Rental of Coal Lands.** Any person, association, co-partnership or corporation, leasing and operating coal land under the provisions of this act, shall pay to the State the minimum price of not less than ten (10) cents per ton for each and every ton of merchantable coal so mined from said land, to be paid monthly on or before the 25th day of each month, for the coal mined during the preceding calendar month. Should the lessee of such coal land fail to mine during any one year the minimum amount that may be provided for in the term of the lease, he shall, notwithstanding such failure, pay to the State the minimum rental provided for in said lease. Should any person apply to lease any of the coal lands belonging to the State, upon which there are surface or underground improvements placed or made by a former lessee, before a lease shall issue, said applicant shall file in the office of the Register a receipt showing that the price of said improvements, as agreed upon by the parties, or fixed by the State Land Agent, or one of his assistants, has been paid to the owner thereof in full, or shall make satisfactory proof that he has tendered to such owner the price of such surface or underground improvements so agreed upon or fixed; or proof that the owner of such improvements elects to remove them.

MINING PARTNERSHIPS.

REVISED CODES 1921.

Section 8050. When a Mining Partnership Exists.
Section 8051. Express Agreement Not Necessary.
Section 8052. Profits and Losses, How Shared.
Section 8053. Liens of Partners.
Section 8054. Mine-Partnership Property.
Section 8055. Partnership Not Dissolved by Sale of Interest
Section 8056. Purchaser Takes Subject to Liens.
Section 8057. Takes With Notice of Lien, When.
Section 8058. Contract in Writing—When Binding.
Section 8059. Owners of Majority of Shares Govern.

Section 8050. **When a Mining Partnership Exists.** A mining partnership exists when two or more persons who own or acquire a mining claim for the purpose of working it and extracting the mineral therefrom, actually engage in working the same.

Section 8051. **Express Agreement Not Necessary.** An express agreement to become partners or to share the profits and losses of mining is not necessary to the formation and existence of a mining partnership. The relationship arises from the ownership of shares or interests in the mine and working the same for the purpose of extracting the minerals therefrom.

Section 8052. **Profits and Losses, How Shared.** A member of a mining partnership shares in the profits and losses thereof in the proportion which the interest or share he owns in the mine bears to the whole partnership capital or whole number of shares.

Section 8053. **Liens of Partners.** Each member of a mining partnership has a lien on the partnership property for the debts due the creditors thereof, and for money advanced by him for its uses. This lien exists notwithstanding there is an agreement among the partners that it must not.

Section 8054. **Mine is Partnership Property.** The mining ground owned and worked by partners in mining, whether purchased with partnership funds or not, is partnership property.

Section 8055. **Partnership Not Dissolved by Sale of Interests.** One of the partners in a mining partnership may convey his interest in the mine and business without dissolving the partnership. The purchaser, from the date of his purchase, becomes a member of the partnership.

Section 8056. **Purchaser Takes Subject to Liens.** A purchaser of an interest in the mining ground of a mining partnership takes it subject to the liens existing in favor of the partners for debts due all creditors thereof, or advances made for the benefit of the partnership, unless he purchased in good faith, for a valuable consideration, without notice of such lien.

Section 8057. **Purchaser Takes With Notice of Lien, When.** The purchase of the interest of a partner in a mine when the partnership is

engaged in working it, takes with notice of all liens resulting from the relationship of the partners to each other, and to the creditors of the partnership.

Section 8058. **How Partnership Bound.** No member of a mining partnership or other agent or manager thereof can, by a contract in writing, bind the partnership, except by express authority derived from the members thereof.

Section 8059. **Majority of Shares Governs.** The decision of the members owning a majority of the shares or interests in a mining partnership binds it in the conduct of its business.

FRAUD IN SELLING MINES, ETC.

Section 11419. Uses of False Pretenses in Selling Mines.
Section 11420. Interference With Samples for Assay.
Section 11421. Making False Samples of Ore.

Section 11419. **False Pretenses in Selling Mines.** Every person who, with intent to cheat, wrong, or defraud, places in or upon any mine or mining claim any ores or specimens of ores not extracted therefrom, or exhibits any ore, or certificate of assay of ore not extracted therefrom, for the purpose of selling any mine or mining claim, or interest therein, or who obtains any money or property by any such false pretenses or artifices, is guilty of a felony.

Section 11420. **Interference With Samples for Assay.** Every person who interferes with, or in any manner changes samples of ores or bullion producing for sampling or changes or alters samples or packages of ores or bullion which have been purchased for assaying, or who shall change or alter any certificate of sampling or assaying, with intent to cheat, wrong, or defraud, is guilty of a felony.

Section 11421. **Making False Samples of Ores.** Every person who, with intent to cheat, wrong, or defraud, makes or publishes a false sample of ore or bullion, or who makes or publishes, or causes to be published a false assay of ore or bullion is guilty of a felony.

SAFETY TO UNDERGROUND MINERS.

REVISED CODES 1921.

Section 11269. Stoping Near Shaft.
Section 11270. Running Cage at Excessive Speed.
Section 11271. Maintaining Buildings Near Mouth of Shaft.
Section 11273. Escapement Shaft.
Section 11274. To What Mines Act Applicable.
Section 11275. Penalty.
Section 3434. Protections and Guard-rails in Case of Shafts and Underground Openings.

Section 11269. **Stoping Near Shaft.** It is unlawful for any corporation or person operating any mine in this State worked through a vertical or incline shaft to stope within a less distance than twenty-five (25) feet of the said shaft when other work is being carried on below said stoping.

Section 11270. **Running Cage at Excessive Speed.** It is unlawful for any person or corporation operating any mine in this State worked through a vertical or incline shaft, where a cage or other device is used for the purpose of hoisting or lowering men, to run such cage when men are upon the same at a greater speed than eight hundred (800) feet per minute.

Section 11271. **Maintaining Buildings Near Mouth of Shaft.** It is unlawful for any person, company or corporation to erect or maintain any building or inclosure, used for a blacksmith shop or drying room within a distance of fifty (50) feet of the mouth of any tunnel or shaft, unless the same be fire-proof in its construction.

Section 11273. **Escapement Shaft.** It is the duty of any person, company or corporation, who shall have sunk on any mine a vertical or incline shaft to a greater depth than one hundred feet, and who shall have the top of such shaft or hoisting opening covered or enclosed by a shaft or building which is not fire-proof, and who shall have drifted on or along the vein or veins thereof, a distance of two hundred feet or more, after cross cutting to the same, and shall have commenced to stope, to provide and maintain to the hoisting shaft or the opening through which men are let into or out of the mine and the ore is extracted, a separate escapement shaft, raise, or opening, or an underground opening or communication between every such mine and some other contiguous mine, provided, that in case such contiguous mine belongs to a different person, company or corporation, the right to use the outlet through such contiguous mine in all cases when necessary, or in cases of accident, must be secured and kept in force. Where such an escapement shaft or opening shall not be in existence at the time that stoping is commenced, work upon such escapement shaft or opening must be commenced as soon as stoping begins and be diligently prosecuted until the same is completed, and said escapement shaft, raise or opening shall be continued to and connected with the lowest workings in the mine. The exit, escapement shaft, raise or opening provided for in the foregoing paragraphs must be of sufficient size as to afford an easy passage way and if it be a raise, or shaft, must be provided with good and substantial ladders from the deepest workings to the surface. Whenever the exit or outlet herein provided for is not a direct or continuous course, signboards plainly marked showing the direction to be taken must be placed at each departure from the continuous course.

Section 11274. **To What Mines Act Applicable.** This Act shall apply only to quartz mines in which nine or more men are employed underground, and shall not apply to mines not actually extracting ores, by stoping, nor to mines in which the shaft or hoisting opening, or hauling way is not covered by a shaft house, and has no building structure within thirty (30) feet of the shaft or opening nor to mines in which the hoisting shaft or opening shall be covered by or enclosed in a fire-proof shaft or building.

Section 11275. **Penalty.** Every person or corporation failing to comply with any of the above sections punishable by a fine of not less than three hundred dollars nor more than one thousand dollars.

Section 3434. **Protections and Guard-rails in Case of Shafts and Underground Openings.** Underground workings consisting of chutes, manways, and winzes, or any openings kept for ventilating purposes, or for the removal of ore or waste material, shall when necessary be protected by guard-rails, or by a suitable cover known as a grizzly, made of good, substantial timbers or metal bars. Shafts at stations shall be protected by guard-rails at every level. In vertical manways used by employes exclusively for traveling purposes, in addition to proper ladders there shall be suitable landings, placed not to exceed thirty feet apart, and so far as feasible and practicable all such manways or air-courses used as an escape for men must be kept free from all obstructions.

CODE OF SIGNALS IN METAL MINES.

REVISED CODE 1921.

Section 3429. Code of Signals in Metal Mines.
Section 3430. Penalties.

Section 3429. **Signals of.** It is made the duty of the inspector of mines of Montana, and he is hereby required to prepare a complete code of signals for the use in all mines in this state, worked through a shaft of seventy-five feet or more in depth, and employing ten or more men, and cause the same to be made known to each owner or operator of a mine in Montana by printed circular instructions, to the end that a uniform code of mine signals may prevail. The said inspector of mines of Montana may add to or change such code of signals as circumstances may require, but no change of signals shall go into effect until a time specified by him, not less than sixty days nor more than ninety days from the time such change shall be ordered by him; provided, that the code of signals first prepared by him shall be used in all said shaft mines from and after June 1, 1895.

Section 3430. **Penalties.** Any owner or operator of a mine who shall refuse or neglect to cause the signals provided for in the preceding section to be used in his mine, to the exclusion of all other signals, shall be deemed guilty of a misdemeanor, and upon conviction of such refusal or neglect shall be fined in a sum not less than one hundred dollars nor more than five hundred dollars, or by imprisonment in the county jail for a period of not less than thirty days or more than ninety days, in the discretion of the court, for each and every offense.

STATE CODE OF MINE SIGNALS.

Signal Bells.

1 bell hoist, 1 bell stop (if in motion).

2 bells lower men, 3 bells hoist men.

4 bells blasting signal, engineer must answer by raising bucket a few feet and letting it back slowly.

Then one bell hoist men away from blast.

5 bells steam on, 6 bells steam off.

7 bells air on, 8 bells air off. 3-2-2 send down drills. 3-2-3 send down picks.

9 bells danger signal (case of fire or other danger), then ring number of station where danger exists. No person shall ring any bell except the station tender, except in case of danger, or when the main shaft is being sunk. Engineers must slow up when passing stations when men are on cage.

Station Bells.

Bells	Pause	Bells	No. Station	Bells	Pause	Bells	No. Station
2	"	1	1	5	"	4	19
2	"	2	2	5	"	5	20
2	"	3	3	6	"	1	21
2	"	4	4	6	"	2	22
2	"	5	5	6	"	3	23
3	"	1	6	6	"	4	24
3	"	2	7	6	"	5	25
3	"	3	8	7	"	1	26
3	"	4	9	7	"	2	27
3	"	5	10	7	"	3	28
4	"	1	11	7	"	4	29
4	"	2	12	7	"	5	30
4	"	3	13	8	"	1	31
4	"	4	14	8	"	2	32
4	"	5	15	8	"	3	33
5	"	1	16	8	"	4	34
5	"	2	17	8	"	5	35
5	"	3	18	9	"	1	36

Where electric bells are used in connection with other bells.

If cage is wanted ring station signal. Station tender will answer 1 bell.

Reply 1 bell to go up.

Reply 2 bells to go below.

If station is full of ore and station tender is wanted, ring station signal and do not answer back.

If 2-1-2 bells are rung, engineer or station tender does not understand, repeat signal.

In case of danger or accident, ring station signal, station tender will reply 1 bell, ring 9 bells.

One copy of this code should be posted on the gallows frame and one before the engineer.

To be in effect from and after June 1st, 1895.

This code is subject to change under certain conditions.

PROCEDURE TO EXAMINE ADJOINING MINING PROPERTIES

REVISED CODE 1921.

Section 9494. Whenever any person shall have any right to or interest in any lead, lode, or mining claim which is in the possession of another person, and it shall be necessary for the ascertainment, enforcement, or protection of such right or interest that an inspection, examination, or survey of such lead, mine, lode, or mining claim should be had or made; or whenever any inspection, examination, or survey of any such lode or mining claim shall be necessary to protest, ascertain, or enforce the right or interest of any person in another mine, lode, or mining claim, and the person in possession of the same shall refuse, for a period of three days after demand therefore in writing, to allow such inspection, examination, or survey to be had or made, the party so desiring the same may present to the district court, or judge thereof, of the county wherein the mine, lead, lode, or mining claim is situated, a petition, under oath, setting out his interest in the premises, describing the same that the premises are in the possession of a party, naming him, the reason why such examination, inspection, or survey is necessary, the demand made on the person in possession so to permit such examination, inspection, or survey, and his refusal so to do. The judge or court shall thereupon appoint a time and place for hearing such petition, and shall order notice thereof to be served upon the adverse party, which notice shall be served at least one day before the day of hearing. On the hearing either party may read affidavits or produce oral testimony and if the court or judge is satisfied that the facts stated in the petition are true, he shall make an order for an inspection, examination, or survey of the lode or mining claim in question, in such manner, at such time, and by such persons as are mentioned in the order Such person shall thereupon have free access to such mine, lead, lode, or mining claim for the purpose of making such inspection, examination, or survey, and any interference with such person while acting under such order shall be contempt of court. If the order of the court is made while an action is pending between the parties to the order, the costs of obtaining the order shall abide in the result of the action, but all costs of making such examination or survey shall be paid by the petitioner.

DESTROYING NOTICES---PENALTY

REVISED CODES.

Section 11491. **Every person who intentionally:**

1. Defaces, obliterates, tears down or destroys any copy or transcript or extract from or of any law of the United States or of this State, or any proclamation, advertisement or notification set up at any place in this State by authority of any law of the United States or of this State or by order of any court, before the expiration of the time for which the same was to remain set up; or,

2. Defaces, obliterates, tears or destroys any notice placed or posted on a mining claim, or removes or destroys any stake or monument placed thereon to identify it,

Is punishable by imprisonment in the county jail not exceeding three months or by a fine not exceeding one hundred dollars, or both.

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STATE OF MONTANA

M. A. BRANNON, *Chancellor, The University of Montana*

BUREAU OF MINES AND GEOLOGY

FRANCIS A. THOMSON, *Director*

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GEOLOGY AND ORE DEPOSITS OF BANNACK AND ARGENTA, MONTANA

by

PHILIP J. SHENON

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PREFACE

Bannack and Argenta are part of the Old West. Bannack was the first placer camp of significance in Montana and the scene of the first successful gold dredging operations in America, whereas it was at Argenta that the first successful lead-silver mining and smelting operations in Montana were begun. At Bannack the wave of civilization sweeping eastward from the Pacific met the westward advancing wave from the Atlantic. It was here that the gap between the two frontiers was closed and that "forty-niners" from California taught men from the "states" to use the pan, the rocker, and the sluice-box.

But the history of the past is only an incidental feature of this publication. The prime purpose is to illustrate the application of the new geology to the old camps in the hope that by careful scientific analysis of the causes which have led to the formation of the bonanzas of the past, stimulus may be given to the revival of productive activity in the future.

Bannack and Argenta are typical of the numerous and more or less deserted mining camps which are dotted as a group of satellites about the Boulder batholith and from which, in the aggregate, several hundred million dollars in gold and silver have been produced. A mine is a wasting asset, and it is doubtless true that certain of the richly productive ore-bodies of the Boulder batholith have been exhausted. On the other hand, it is doubtless equally true that certain mines of the past were abandoned either because of failure to understand the genesis and structure of the ore-bodies, or because of inability to deal successfully with the refractory and complex ores by the metallurgy then current.

To the solution of the problems—geological and metallurgical—presented by these formerly productive areas, the Bureau hopes to make a substantial contribution through such studies as are typified by this publication, "The Geology and Ore Deposits of Bannack and Argenta." It has been the endeavor throughout the preparation of this report to make it easily understood by the intelligent miner, prospector, and layman; but at the same time to include the essential basic scientific facts needed by the trained geologist or engineer in order that he may make an intelligent detailed examination of a specific property, for without a favorable report from a competent engineer there is no hope of interesting capital in mining development.

FRANCIS A. THOMSON, *Director.*

THE GEOLOGY AND ORE DEPOSITS OF BANNACK AND ARGENTA, MONTANA

By Philip J. Shenon

SUMMARY

The areas described in this report include 30 square miles near Bannack and 20 square miles in the immediate vicinity of Argenta, Montana. The Argenta area lies 5 miles northeast of the Bannack area.

These two districts include the first important placer and lode mines in Montana, and many of them have been worked intermittently up to the present time. The mines have produced gold, silver, lead, zinc, and copper in considerable quantity. The total production of the Bannack area is estimated at $12,000,000 and that of the Argenta area at $1,500,000.

The oldest known rocks of sedimentary origin exposed in the Bannack district are limestones of Mississippian age. The youngest stratified rocks exposed in the vicinity are "Red Beds" of probably Triassic age. Consolidated sedimentary rocks ranging in age from pre-Cambrian to Pennsylvanian are found in the Argenta area. They include thick deposits of limestones, quartzites, and shales. The unconsolidated materials include terrace gravels and glacial moraine. Because of their positions the terrace gravels have been classified into "Upper Bench Gravels" and "Lower Bench Gravels".

Former igneous activity manifests itself in both areas as flows, tuffs and intrusives. The ore deposits are closely related to intrusive rocks of intermediate composition.

All of the consolidated rocks have been folded and displaced by overthrust faulting. Normal faults have caused displacements on a smaller scale.

Valuable ore deposits occur in both sedimentary and intrusive rocks but are everywhere located at or near the intrusive contacts. Most of the deposits were small or moderate in size but practically all were high grade. The deposits with obvious exposures have been largely exhausted but it is altogether possible that additional discoveries may be made.

INTRODUCTION

PURPOSE AND SCOPE OF THE REPORT

The first part of the field work for the Bannack report was done during the summer months of 1925. Another month was spent at geological investigation in 1928. The field work for the Argenta report covered a period of nearly two months during the summer of 1929.

The report on the Bannack area was first assembled at the University of Minnesota[1] during the winter and spring of 1925-26 and, except for condensation and rearrangement and the added description of the Hendricks mine, remains essentially as originally written. The Argenta report was prepared during the spring and summer of 1930 at the Montana School of Mines.

Section corners served as the principal horizontal control for the construction of the topographic maps whereas the secondary points were located by Brunton intersections and by pacing. The plane-table was used for part of the work in the Bannack area but all of the elevations in the Argenta area were determined by aneroid barometer. The formation boundaries were followed out and mapped and are delineated as accurately as the topography. Broken lines are used where the contacts are doubtful.

Fifty mines and prospects were visited during the course of the work but due to the pressure of time only a few of them were mapped. However, the characteristics of each have been described in more or less detail.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the numerous courtesies which have facilitated the field work. Among many others, Messrs. William Dunn, C. H. Stallings, Frank Sinnott and F. L. Graves (now deceased) of Bannack; George Metlen, John Coppin, J. B. Somers, D. V. Erwin, William Corbett and G. V. Elder of Dillon; A. H. French, George W. French, W. J. Cushing and George Knapp of Argenta; and Alexander Leggat and Samuel Barker, Jr., of Butte, were generous in giving time and information.

1. A report on the geology of the Bannack district was submitted by the writer to the Graduate School of the University of Minnesota in partial fulfillment for the degree of Doctor of Philosophy.

During the preparation of the Bannack report the writer received assistance and many suggestions from the members of the Geology Department of the University of Minnesota. Special acknowledgment is due Dr. W. H. Emmons and Dr. F. F. Grout for helpful suggestions and criticisms. Mr. R. J. Leonard identified the fossils that served to correlate the sedimentary rocks. Acknowledgment also is due Dr. G. M. Schwarts for assistance and advice rendered during the study of the polished sections. Mr. W. S. Yarwood made one complete rock analysis and Dr. R. J. Leonard one incomplete analysis.

The writer wishes to express his thanks to President Francis A. Thomson of the Montana School of Mines for his help and criticism throughout the preparation of the report. Thanks are also due Dr. E. S. Perry for his criticism and for assistance in photography. Mr. L. H. Hart of the Anaconda Copper Mining Company was generous with information and comments on the geology of the Tuscarora and Governor Tilden mines. Mr. George H. Girty of the U. S. Geological Survey identified the fossils from the Argenta district. Credit is due Mr. Romer H. Guenther and Mr. S. F. Hornbeck of the Anaconda Copper Mining Company for the drafting of the maps.

GEOGRAPHY

SITUATION

The Argenta and Bannack areas (fig. 1) are centrally located in Beaverhead County, southwestern Montana, and for the most part lie within the Dillon Quadrangle[2]. The Argenta area is in T. 9 S., Rs. 11 and 12 E., and comprises an area of 20 square miles; the Bannack area is in Tps. 7 and 8 S., R. 11 W., and includes an area of 30 square miles. The Blue Wing mining district occupies approximately the northern half of the Bannack area and the Bannack mining district the southern half (Pl. I).

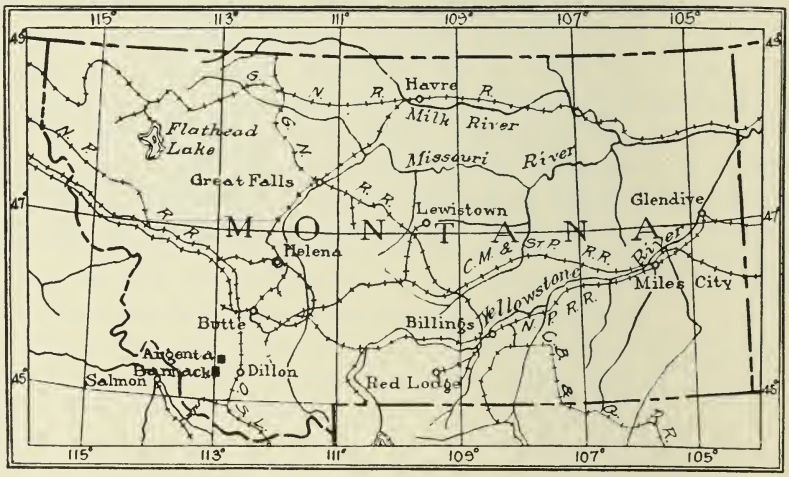


FIGURE 1. INDEX MAP OF MONTANA SHOWING BANNACK AND ARGENTA

Dillon is the nearest railroad shipping point for the Argenta and Blue Wing districts which lie, respectively, 14 and 18 miles west of Dillon. Ore from Bannack is shipped from Grant, 12 miles to the west, on the Gilmore and Pittsburgh railroad. A direct water-grade highway to connect Bannack with the Oregon Short Line railroad at Barratt Station, a distance of about 14 miles, is under consideration.

TOPOGRAPHY

The Bannack and Argenta areas lie in a section of the Rocky Mountain province characterized by a series of north-south trending mountain ranges which are separated by broad intermontane troughs. The main mountain masses are well rounded and charac-

2. Winchell, A. N., U. S. Geol. Survey Bull. 574, 1914.

terized by flat summit areas which Umpleby[3] has described as an old erosion surface. The smooth mountain slopes are, however, dissected by steep V-shaped valleys that have locally been widened by glaciation.

The maximum relief within the mapped areas is approximately 1800 feet. The highest point in the region, Robbers' Roost, is located in the northern part of the Bannack district; it attains an altitude of 7600 feet (Pl. I) and because of its prominence was used as a lookout station by the early-day road agents, and hence the name. The lowest point is just south of the junction of Spring Gulch and Grasshopper Creek at an elevation of 5800 feet. The high range, composed largely of tilted limestones and quartzites, running north and south through the Bannack and Argenta areas weathers into sharp cliffs and jagged gulches in marked contrast with the more rounded topography developed in the gravels to the west and the lavas and gravels to the east of this central highland.

The region described in this report is drained by Rattlesnake and Grasshopper Creeks, both of which flow into Beaverhead River, a large tributary of the Missouri. Rattlesnake Creek has its headwaters in a series of wide glaciated valleys south of Mt. Torrey. Thence it flows southeastward, partly through glacial debris, to a point about 4 miles from Argenta, where the creek leaves the narrow V-shaped valley to enter a wider valley through which it travels the remainder of its course to Beaverhead River, four miles south of Dillon. Near Argenta, Rattlesnake Creek has carved a well-defined terrace into gravel beds deposited by an ancient drainage system[4].

Grasshopper Creek rises near the base of Baldy Mountain and flows southward through a wide, alluvial-filled valley for about 20 miles and then, west of Bannack, turns almost at right angles and flows the remainder of its course through a narrow gorge, whereas the ancient gravel-filled stream channel continues southward to Horse Prairie Creek. According to Atwood[5], the early Tertiary drainage of southwestern Montana was to the southwest instead of to the northeast as it is today. After the early Tertiary drainage was blocked by lava flows and warping, there followed a long period of deposition in the intermontane basins while the headwaters of the Missouri were advancing westward. By active headward erosion the Missouri finally captured the drainage of southwestern Montana; and yet, for the most part, the present drainage, although

3. Umpleby, J. B., Jour. of Geol., vol. 20, pp. 139-147 (1912).
4. Atwood, W. W., Economic Geology, vol. 11, No. 8, pp. 698-732, 1916.
5. Op. cit.

reversed in direction, still follows the ancient stream valleys. Immediately west of the mapped area, Grasshopper Creek follows one of these old valleys to a point not far from Bannack where the stream is sharply diverted eastward through a youthful valley to Beaverhead River. The apparent entrenchment meandering in the NW.¼ of sec. 16 is due to the adjustment of the stream to the rock structures during headward erosion and is entirely local (Pl. IV-B).

CLIMATE AND VEGETATION

The climate is semi-arid, the annual precipitation ranging from 15 to 20 inches. The summers are warm and pleasant but the winters are usually cold. The mean average temperature is about 42 degrees F. and the extreme maximum and minimum temperatures are about 90 degrees F. and 30 degrees F., respectively. The following tables give precipitation and snowfall data for Dillon but can be considered as representative of Bannack and Argenta[6]:

Monthly and Annual Precipitation, in Inches, at Dillon, Montana (1920)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
.35	1.40	1.71	1.95	3.41	2.44	2.70	0.91	1.26	0.88	0.51	0.40	17.92

Monthly and Annual Snowfall, in Inches, at Dillon, Montana (1920)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
3.0	8.0	4.1	11.0	Tr.	0.0	0.0	0.0	3.0	2.0	5.0	3.5	39.6

Medium-sized evergreen trees are quite abundant although in certain sections of the area the timber has been nearly depleted. The remaining timber is practically limited to the highland area extending north and south through the region. Only isolated patches of timber grow in the areas occupied by the volcanic rocks and much of the accessible timber in the lowlands has been utilized. Sufficient timber for extensive mining operations is, however, still available. Most of the untimbered country is covered with greasewood and sagebrush. Bunch grass is abundant so that the region supports a considerable number of sheep and cattle during the grazing season.

6. Report of the Chief of the U. S. Weather Bureau for 1920-21.

BIBLIOGRAPHY

The large scale topographic map of the Dillon Quadrangle prepared by Frank Tweedy in 1887 and 1888 for the United States Geological Survey, includes the Argenta district and the eastern part of the Bannack area, as mapped by the writer. The scale of the map is 1 to 250,000 or about four miles to the inch, and the contour interval is 200 feet. The following publications relate to the geology and mining industry of the Argenta and Bannack districts:

1868. BROWNE, J. ROSS, Mineral resources of the United States for 1866, Montana, pp. 498-506.

1868. KEYES, W. S., Mineral resources of the United States for 1866, Appendix, pp. 38-56.

1869-1877. RAYMOND, R. W., EATON, A. K., WHEELER, W. F., etc. Mineral resources of the region west of the Rocky Mountains, for 1869, pp. 134-152; for 1870, pp. 204-217; for 1871, pp. 261-273; for 1872, pp. 216-221; for 1873, pp. 367-374; for 1874, pp. 323-327; for 1875, pp. 237-245.

1885. LEESON, M. A., History of Montana, 1739 to 1885, Chicago, 1885, 1867 pages.

1885. EMMONS, S. F., Geological sketch of the Rocky mountain division: Tenth Census, vol. 13, pp. 94-100.

1890. BANCROFT, H. H., History of Washington, Idaho, and Montana, 1848 to 1889, San Francisco, 1890, pp. 589-808, particularly pp. 620-627, and pp. 721-728.

1897. BARREL, R. W., The mineral formation of the Golden Leaf mines (Beaverhead County, Montana): Eng. and Min. Jour., vol. 64, p. 64.

1903. WEED, W. H., Ore deposits near igneous contacts: Trans. A. I. M. E., vol. 33, p. 732.

1905. DOUGLAS, E., Some notes on the geology of southwestern Montana: Carnegie Museum Memoir 3, pp. 407-428.

1914. WINCHELL, A. N., Mining districts of the Dillon Quadrangle, Montana and adjacent areas: U. S. Geol. Sur. Bull. 574.

1915. BILLINGSLEY, PAUL: The Boulder Batholith of Montana: Trans. A. I. M. M., vol. 51, pp. 31-56.

1915. NOYES, A. J., Dinsdale's Vigilantes of Montana, Montana State Publishing Co., Helena, Montana.

1916. ATWOOD, W. W., The physiographic conditions at Butte, Montana and Bingham Canyon, Utah, when the copper ores in these districts were enriched: Econ. Geol. vol. 11, No. 8, pp. 697-740.

1916. BILLINGSLEY, PAUL, and GRIMES, J. A., Ore deposits of the Boulder Batholith of Montana: Trans. A. I. M. E., vol. 58, pp. 284-361.

1916. JENNINGS, HENNEN, The history and development of gold dredging in Montana: U. S Bureau of Mines Bull. 121.

1927. SHENON, P. J., Gold at Bannack, Montana: Eng. and Min. Jour., vol. 123, p. 326.

1930. FRENCH, G. W., Argenta, first lead-silver camp in Montana, still shipping ore: Mining Truth, Spokane, Wash., April 3, 1930, p. 23.

THE BANNACK AREA

GENERAL GEOLOGY

CHARACTER AND DISTRIBUTION OF THE ROCKS

The prevailing rocks of the region are igneous and are most abundant in the eastern half of the area. They include granodiorite, andesite, dacite, rhyolite and basalt. Of these the extrusive rocks greatly predominate.

The sedimentary section in the Bannack district is far from complete, although over 2000 feet of sediments are included, ranging in age from Lower Mississippian to unconsolidated Quaternary gravels. Limestones of Mississippian age are widespread, but Jurassic and Cretaceous sediments were not observed. Erosion has removed the consolidated post-Carboniferous sedimentary rocks except where they have been protected by overthrust faulting. The distribution of the rocks is shown on the geologic map forming Plate I.

CARBONIFEROUS SYSTEM

MADISON FORMATION

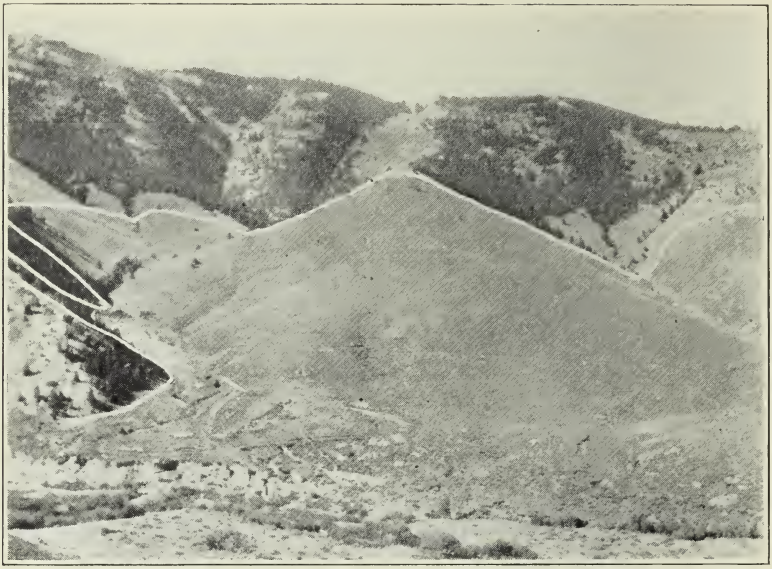
The Madison formation, consisting mainly of grayish-blue limestone, is very well developed in the Bannack region where it attains a thickness of about 1200 feet. Although the base of this formation was not definitely fixed, fossil evidence indicates the presence of the basal beds. Some grayish-green and maroon-colored shales, immediately west of the fault in the SE.¼ of sec. 8, were tentatively mapped with the Madison although no fossils to fix their age were found.

About 200 feet of the lowest exposure of the Madison formation is comprised of alternating grayish-blue, bluish-white, and pinkish crystalline limestone. Above this comes about 200 feet of bluish-gray limestone with abundant organic remains. Then follows about 150 feet of dark grayish-blue limestone with numerous lenses and nodules of grayish-black and black chert. This is followed by about 400 feet of massive grayish-blue limestone, while nearer the top the formation becomes predominantly red in color and the rocks are more arenaceous. A peculiar grayish-blue conglomerate composed of limestone fragments was noted near the top of the formation. It is exposed on the high point in the W.½, sec. 17. Although the red arenaceous limestones were mapped with the Madison formation it is quite possible that they correspond with

7. Peale, A. C., U. S. Geol. Survey Folio 24, p. 2, 1896.

A. BANNACK, MONTANA, LOOKING NORTHEAST. TERTIARY GRAVELS IN LEFT BACKGROUND AND TILTED LIMESTONE IN RIGHT BACKGROUND.

B. TILTED FLATHEAD QUARTZITE (center) JUST EAST OF FRENCH CREEK, ARGENTA DISTRICT. THE QUARTZITE BORDERS SPOKANE SHALE WHICH OCCUPIES THE CENTER OF A BROAD ANTICLINAL FOLD.



A. INTRUSIVE CONTACT OF GRANODIORITE WITH MADISON LIMESTONE JUST EAST OF BANNACK. NOTE APOPHYSIS OF INTRUSIVE EXTENDING INTO LIMESTONE IN LEFT FOREGROUND.

B. ADJUSTMENT OF GRASSHOPPER CREEK TO THE TILTED "RED BEDS" IN THE N.W.¼ OF SEC. 16

north of Mann Gulch where it occupies two synclinal troughs. the "red" limestones of the Three Forks area[7] where they are included with the Quadrant formation. Fossils from the Argenta district identified by G. W. Girty of the U. S. Geological Survey, indicate that limestones of both Brazer (upper Mississippian) and Wells (Pennsylvanian) age are present in that district, and a more complete fossil collection from the Bannack region will, no doubt, prove the same thing to be true in that area. The fossils collected from the Madison formation were identified by Dr. R. J. Leonard and are listed below:

Amplexus sp.
Camarotechia metallica
Camarotechia sp.
Cleiothyris roissyi
Crania laevis
Crinoid stem fragments
Cyathophyllum sp.
Derbya crassa?
Eumetria marcyi
Fenestella sp.
Murchisonia sp.
Nodosinella
Orthotetes inflatus?
Pleurophorus sp.
Productella concentrica?
Productus arcuatus
Productus cora
Productus laevicostus
Productus semireticulatus
Rhombopora sp.
Schizophoria swallovi
Spirifer centronatus
Spirifer (Delthyris) cf. tullius
Spiriferina cristata
Spirifer rockymontanus
Straparollus luxus?
Straparollus cf. similis
Syringopora sp.
Zaphrentis excentrica
Zaphrentis stansburyi

QUADRANT FORMATION

The Quadrant, which overlies the Madison formation, is exposed mainly in the extreme northern and southern ends of the area. It consists predominantly of quartzite which grades upward into a fine-grained sandstone. Talus developed on the steep slopes by the weathering of these rocks usually conceals the contacts with the other formations. The top of the formation has been removed by erosion but the base is well exposed in the saddle just south of Bannack Point where it rests upon a bed of woody-appearing shale about two feet in thickness. Beneath this woody-appearing shale is a thin layer of black organic shale, less than an inch in thickness, which in turn rests upon a massive blue limestone. Beneath this blue limestone are the red and pink arenaceous limestones. The vitreous quartzite which comprises the lower part of the Quadrant formation is white or pinkish-white in color but weathers to reddish-brown on exposed surfaces. Bedding was not recognized. Because of the intense fracturing and jointing the quartzite has a hackly appearance. Microscopic examination proved this to be an unusually pure quartzite composed largely of rounded quartz grains, showing marked secondary growth, with some interstitial silica and a few isolated grains of biotite. The quartz grains are uniform in size and average about 0.15 mm. in diameter. The thickest section of the Quadrant formation is exposed just

The synclinal trough occupied by Robbers' Roost, the highest point in the region, includes a section over 500 feet in thickness.

The age of the formation correlated with the Quadrant is probably Pennsylvanian. Calkins[8] obtained Pennsylvanian fossils from the Quadrant formations in the Philipsburg quadrangle and Girty[9] regards the fossils found in the Quadrant formation of the Snowcrest mountains, southwest of Virginia City, as of early Pennsylvanian age. No fossils were obtained from this formation in the Bannack district, but those found in the red arenaceous limestones beneath it were identified as upper Madison. Fossils of probable Wells (Pennsylvanian) age were found in limestone beds beneath the quadrant quartzite in the Argenta district.

MESOZOIC SYSTEM

"RED BEDS"

The "Red Beds" are exposed for the most part in the southern end of the area, disconformably underlying Madison limestones. Their preservation is due largely to the fact that the overthrust Madison limestones have protected them from erosion.

The "Red Beds" consist largely of alternating beds of red conglomerate and sandstone with some beds of grayish-blue conglomerate. The beds are persistent and range in thickness from about 1 to 20 feet. The pebbles in the conglomerates vary considerably in composition, size, and angularity. Although blue limestone pebbles often containing organic remains typical of Madison limestone predominate, brown and white quartzite, pink, buff, and black chert, brown sandstone and white quartz pebbles are common. The largest pebbles observed were less than a foot in diameter, but the average size is probably less than an inch. The quartzite, sandstone, quartz, and chert pebbles are usually well rounded, whereas those of blue limestone are frequently angular. Both sandstone and conglomerate are well cemented, the latter usually with a brownish-red to brick-red sandy material. Several beds of volcanic rocks, purplish to pinkish in color, are present in the lowest exposed portions of the "Red Beds". They are in well defined beds and are clearly members of the strata that comprise the "Red Beds". The microscope shows these rocks to be made up largely of volcanic glass, some with marked flow structures (Pl. VI, 3). Although these rocks are greatly altered, several feldspars showing carlsbad twinning could be seen and one with albite twinning showed

8. Emmons, W. H., and Calkins, F. C.: U. S. Geol. Sur. Prof. Paper 78, pp. 70-74, 1913.
9. Condit, D. Dale: U. S. Geol. Sur. Prof. Paper 120, p. 116, 1919.

an extinction angle of 10 degrees. As quartz was observed, the rocks are probably trachyte or latite, porphyry and tuff.

Neither the top nor the bottom of the "Red Beds" are exposed. Erosion has removed the upper members while the lower beds are in fault-contact with the Madison limestone. The thickness from the contact with the Madison limestone to the exposed top on the south side of Grasshopper Creek was measured roughly and approximates 700 to 800 feet. Cross sections indicate a thickness of at least 1500 feet.

No fossils were found in the "Red Beds" except those included in Madison pebbles. They probably correspond, however, with the Chugwater formation (Permian and Triassic) of southwestern Montana[10] and Wyoming[11] and, to the north, of the Pryor Mountains near Billings, Montana[12].

TERTIARY GRAVELS

The extreme western part of the region is occupied by Tertiary gravels, and terrace gravels are found above Grasshopper Creek in several places (plate I).

The predominating rock is red quartzite, but light-colored quartzite comes next in order. The pebbles are well rounded and although usually about two inches in diameter, they vary from less than an inch to about a foot. Lesser amounts of angular limestone fragments, as large as three feet in diameter, and some sandstone and lava pebbles are present as are a few rounded pebbles of magnetite. The gravel is cemented with coarse sandy material and is quite well indurated.

The gravels are later than the volcanic rocks of Tertiary age and antedate the advent of stream piracy in the region. According at Atwood[13] the closed drainage of southwestern Montana was opened by stream piracy during middle Pliocene.

AURIFEROUS GRAVELS

Most of the auriferous placer gravels are in the present stream channel, although some of the older "bench gravels" were also mined for their gold content. The stream gravels include pebbles of all the rock formations of the region as well as some not found in the vicinity but red quartzite pebbles predominate.

10. Condit, D. Dale, op. cit. p. 119.
11. Darton, N. H., U. S. Geol. Sur. Prof. Paper 40, p. 140, 1906.
12. Kemp. J. F. and Billingsley, Paul, Bull. Geol. Soc. America, vol. 32, p. 466, 1921.
13. Atwood, W. W., op. cit. p. 706.

INTRUSIVE IGNEOUS ROCKS

GRANODIORITE

Granodiorite, the characteristic intrusive rock of the Bannack area, is exposed in both the Bannack and Blue Wing mining districs. In all, the exposures aggregate less than two square miles. These small outcrops are probably isolated exposures of the main Boulder batholith[14].

The Boulder batholith[15] is exposed over an area of 1100 square miles in the mountainous region of western Montana. This batholith is probably a satellite of the Idaho batholith which is situated 150 miles to the west and covers and area of 20,000 square miles[16]. Between the two are many smaller exposures of intrusive rocks. Field work indicates a genetic relationship between the isolated exposures of granitic rocks in Montana so that Billingsley[17] has enlarged the term "Boulder Batholith" to include the outlying tracts.

The prevailing rock of the Bannack district is a fine-grained, medium-to-dark-colored granodiorite. It is more basic and noticeably finer than the prevailing rocks of the greater portion of the Boulder batholith[18] and quartz is not readily discernable in the hand speciman.

In the Bannack mining district there are three distinct outcrops of the granodiorite but in the Blue Wing mining district, with the exception of several small exposures, it occurs as a continuous mass. Although a number of apophyses extend out into limestone, the exposures are more or less elliptical in outline.

The intrusive nature of the granodiorite is made evident by the marked contact metamorphism in the sediments about the edges, by the projection of apophyses into the sedimentary rocks, and by the manner in which the granodiorite truncates the upturned beds of Madison limestone. Garnetization is common along the contact between the granodiorite and the limestone in the Blue Wing district and extensive in the Bannack vicinity. Apophyses of granodiorite can be observed extending into the limestone in the Barton drift at the Kent mine and in a prospect hole just northwest of the Del Monte shaft. Some of the important ore deposits at Bannack occur along apophyses that cut across bedded limestone; the Excelsior mine furnishes a splendid example.

The upper surface of the intrusive masses are rudely dome-

14. Billingsley, Paul, Trans. A. I. M. E., vol. 51, pp. 31-56, 1915.
Winchell, N. H.: U. S. Geol. Sur. Bull. 574, p. 55, 1914.
15. Weed, H. W., U. S. Geol. Sur. Butte Special Folio, 1897.
16. Umpleby, J. B., Jour. of Geology, vol. 20, p. 145, 1912.
17. Billingsley, Paul, op. cit.
18. Weed, W. H., op. cit.; Knopf, Adolph, op. cit.

like but they cut across the bedding and are not laccoliths in the strict sense of the term. The outcrops lack the more rugged features developed in the tilted limestone and are eroded into well rounded topographic forms (Pl. IV. 1). The rock is traversed by pronounced systems of closely spaced joints and tends to break into small rhomboidal-shaped blocks upon weathering. Because of this pronounced jointing the granodiorite has no economic value as a building stone.

In the Bannack mining district all the contacts are sharp and boundaries were easily mapped, but in the Blue Wing mining district the intrusive rocks are in contact, on the east, with an altered grayish-green rock of slightly porphyritic or fine texture which closely resembles the granodiorite, and, as a result, considerable difficulty was experienced in mapping. Microscopic study proved this green porphyry to be an altered phase of a volcanic rock.

PETROGRAPHY

The granodiorite is prevailingly fine-grained and grayish to grayish-green in color. Feldspars constitute about 75 per cent of the rock and biotite, hornblende and magnetite make up the greater part of the remainder. Quartz is not readily discernible in the hand specimens. Pyrite commonly occurs along joint planes.

In thin sections the microscope shows the bulk of the rock to be made up of lath-shaped plagioclase feldspars, usually striated which show very marked zoning and usually, reaction rims (Pl. V). The extinction angles on the twinned plagioclase indicates a composition of Ab_{63} An_{37}, whereas the composition calculated from the norm is Ab_{58} An_{42}. The andesine crystals vary in size from about 0.03x0.05 millimeters to 0.28x0.70 millimeters and average about 0.14x0.20 millimeters. Optically abnormal orthoclase is present largely as interstitial material but generally constitutes about 15 per cent of the rock. The feldspars are usually fresh but occasionally have a dusty appearance. The central zones of the plagioclase show the most alteration, largely to sericite and kaolin. Small amounts of interstitial quartz are present, generally less than 15 per cent. Biotite is the commonest dark constituent and makes up about 10 per cent of the rock. It frequently shows alteration to chlorite. The biotite often includes magnetite, plagioclase and zircon poikilitically, the zircon showing pleochroic haloes. Green hornblende is usually present in amounts ranging from 5 to 10 per cent. Sometimes brown biotite takes the place of hornblende, especially around the borders. The hornblende is usually somewhat altered

to chlorite, epidote, limonite and calcite. Augite is generally present in small amounts. Magnetite, apatite, zircon, and titanite occur as accessory minerals. Magetite grains, commonly square in outline, are disseminated through the sections but are most abundant in or near the ferromagnesian minerals. Magnetite usually comprises from 1 to 5 per cent of the rock but apatite, zircon, and titanite generally make up less than 1 per cent.

A complete chemical analysis of the Bannack intrusive and a partial analysis of a contact phase are given below. Analysis of rocks from the Elkhorn intrusive and from the main Boulder batholith are included in the table for comparison.

Analysis of intrusive rocks from Bannack and adjacent areas

	1	A	B	C	2
SiO_2	61.21	60.84	63.87	64.17	46.65
Al_2O_3	15.20	16.36	15.39	15.25	13.79
Fe_2O_3	2.49	2.40	1.93	2.16	10.17
FeO	3.30	3.23	3.08	2.98	
MgO	4.12	3.85	2.23	2.60	6.75
CaO	6.05	4.96	4.30	4.24	19.42
Na_2O	3.32	2.90	2.76	2.62	
K_2O	2.31	4.10	4.18	4.34	
H_2O	.92	1.03	.69	.65	
H_2O	.21	.48	.19	.16	
TiO_2	.62	——	.65	.67	
	99.78	100.15	99.28	99.84	96.78

1. Bannack, Mont., W. S. Yarwood, analyst, Biotite hornblende granodiorite.
A. Elkhorn district, Montana, E. C. Sullivan, analyst, Mica diorite.
B. Butte, Mont., Alice Mine, W. F. Hillebrand, analyst, Quartz monzonite.
C. Helena, Mont., Frohner Mine, H. N. Stokes, analyst, Quartz monzonite.
2. Bannack, Mont., R. J. Leonard, analyst, Contact phase of granodiorite.

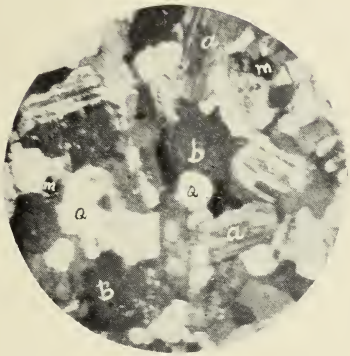
The normative mineral composition as calculated from the chemical analysis according to the rules proposed by Cross, Iddings, Pirrson and Washington[19] may be stated as follows:

	1	A	B	C
Quartz	15.18	11.10	18.84	19.38
Orthoclase	13.34	24.46	25.02	25.58
Albite	27.77	24.63	23.06	22.01
Anorthite	20.02	19.19	17.23	16.96
Diopside	7.97	4.48	2.72	2.69
Hypersthene	9.41	11.27	7.57	7.84
Magnetite	3.71	3.48	2.78	3.25
Ilmenite	1.22		1.22	1.22

Comparison of chemical analysis and normative calculations brings out a marked relationship between the main Boulder batholith and the satellites exposed at Bannack and Elkhorn.

Although the intrusive rock near the contact is essentially the same as the central masses certain changes were noted. At some places along the main contact, and particularly where blocks of limestone were included in the granodiorite, the intrusive rocks were greenish-black to almost black in color or in some cases of a salt and pepper appearance with greenish-black orbicular segregations, generally about an inch in diameter. Under the microscope

19. Washington, H. S., U. S. Geol. Sur. Prof. Paper 99, 1917.



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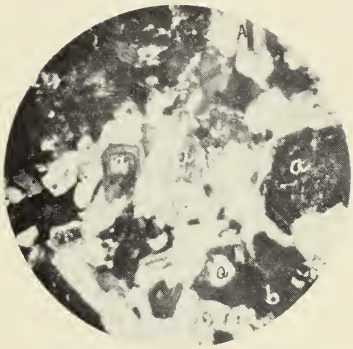

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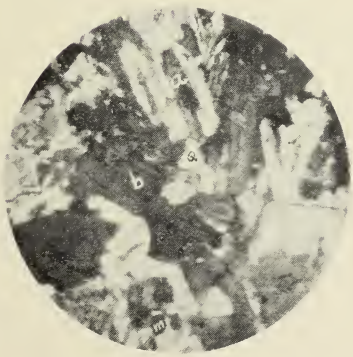

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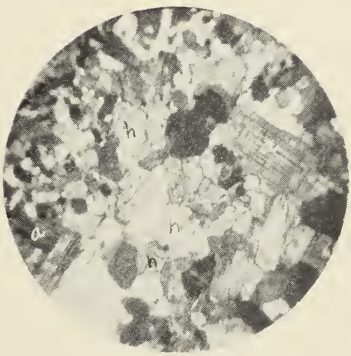

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PHOTOMICROGRAPHS OF GRANODIORITE FROM THE BANNACK DISTRICT, MONTANA.

1. Typical granodiorite from the main intrusive south of Grasshopper Creek, Bannack mining district. Andesine feldspar (a), biotite (b), magnetite (m), quartz (q). Polarized light. Magnification 45 times.
2. Same showing zonal growth in andesine feldspars. Polarized light. Magnification 45 times.
3. Typical granodiorite from the Blue Wing mining district. Andesine feldspar (a), biotite (b), magnetite (m), quartz (q). Polarized light. Magnification 45 times.
4. Granodiorite from near limestone contact. Hedenbergite (h), andesine feldspar (a), quartz (q). Polarized light. Magnification 7 times.

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these dark-colored rocks were found to be made up largely of iron-bearing pyroxene (hedenbergite 70 per cent, diopside 30 per cent) with lesser amounts of plagioclase. No biotite or hornblende was observed in the thin sections studied (Pl. V, 4). This type of variation was observed in the Golden Leaf mine. However, here the intrusive contained noticeable amounts of chalcopyrite and pyrite. In some places on the surface it was possible to trace the gradation from the hedenbergite phase into a light green garnetized limestone which the microscope showed to be made up almost entirely of isotropic garnet. The absence of biotite and hornblende and the very marked increase in hedenbergite confirms the data of the analysis which shows that there was an addition of lime, magnesia, and iron. The relationships of the hedenbergite rock with the limestone contacts and particularly with the blocks of limestone included in the intrusive would suggest the limestone as the source of the lime and possibly some magnesia. The additional iron and magnesia must have been derived from the intrusive itself because an analysis shows the white crystalline limestone, some distance from the contact, to be very pure. The results of the analysis of the crystalline limestone are given below. This variation is therefore considered to be largely an endomorphic contact effect.

EXOMORPHIC CONTACT EFFECTS

Contact effects of the granodiorite were observed only in the limestone so that the alterations produced were quite similar from place to place. The most marked metamorphism was observed along the apophyses where the contacts were exposed by mining operations, as at the apex of the arm-like extension of the granodiorite into the limestone at the Excelsior mine.

A common effect observed was the marmarization of the limestone near the contacts with the intrusive rock. The recrystallization may be due in part to movement because white marble is at places found away from the intrusive contacts. An analysis of a specimen of the white marble from just west of the Bannack Gold Mining Company mill gave the following analysis:

$CaCO_3$	97.14
$MgCO_3$	1.17
Impurities (Fe, SiO_2, Al)	1.12
	99.43

Garnetization is common near the contacts of the intrusive with the limestones. At the surface the garnetized limestone has a citron color but the garnets observed underground were predomin-

antly brownish or reddish-brown. Several other minerals were noted with the garnet but epidote is probably the most common.

AGE

The age of the granodiorite in the Bannack district has not been definitely fixed. These intrusive rocks are known, however, to be later than the folding and probably later than the thrust faulting. The "Red Beds" are the youngest rocks of the district known with certainty to be involved in the folding and thrust faulting; therefore the granodiorite in this region is at least as late as Mesozoic.

Although Weed[20] assigned a Miocene age to the Boulder batholith, more recent work indicates it to be Eocene or late Cretaceous in age.[21] Some of the larger exposures are known to intrude rock of Livingston (late Cretaceous) age[22] and the main Boulder batholith is overlain by Oligocene sediments west of Cliff Mountain[23] and at Pipestone Springs, near the southwest portion of the mass.[24]

Since it is believed that the outlying granitic masses in western Montana are isolated exposures of the main Boulder batholith, the granodiorite at Bannack can be tentatively assigned to late Cretaceous or Eocene.

BASIC DIKES

Only two dikes were noted cutting the limestone. A grayish-black, fine-grained dike with glassy borders cuts the garnetized limestone immediately east of the open pit at the Gold Bug mine. It strikes N. 50 degrees E., and dips 60 degrees N. Another dike was noted in the Norman stope of the Wadams mine. It is fine-grained and somewhat lighter colored than the one at the Gold Bug mine. It strikes N. 40 degrees E., and dips 70 degrees S. The microscope proved the specimen from the first dike to be a basalt. The second was not studied under the microscope.

EXTRUSIVE IGNEOUS ROCKS

DISTRIBUTION AND THICKNESS

Volcanic rocks consisting of varieties of andesite, dacite, rhyolite, and basalt occupy half of the mapped area. The lavas extend from the level of Grasshopper Creek, at an elevation of 5,800 feet, to an elevation of 7,100 feet on the high point in sec. 11, but no

20. Weed, W. H.: U. S. Geol. Sur. Prof. Paper 74, p. 29, 1912.
21. Knopf, Adolph,: U. S. Geol. Sur. Bull. 527, p. 34, 1913.
22. Emmons, W. H. and Calkins, F. C.: U. S. Geol. Sur. Prof. Paper 78, p. 83, 1926.
22. Stone, R. W. and Calvert, W.R.: Econ. Geol. vol. 5, pp. 551-557, 662-669, 744-764, 1910.
23. Douglas, Earl: Annals Carnegie Mus. Pittsburg, vol. 5, pp. 197, 263, 1909.
24. Mathew, W. D.: Bull. Am. Mus. Nat. Hist. vol. 19, p. 197, 1903.

remnants of them were found above that elevation. The relationship of the volcanic rocks was not studied in detail nor could the distance to which they extend below the present drainage lines be determined, but it is certain that they accumulated to a great thickness.

ANDESITE

GENERAL CHARACTER

Andesite, consisting largely of unbroken flows but with lesser amounts of breccias and tuffs, is the commonest volcanic rock of the Bannack region. Although, when examined in detail, they comprise a number of varieties, two types predominate. The commonest variety is a grayish-green, fine-grained rock which usually shows well-developed flow banding and prominent, rhombic-shaped, white phenocrysts. The other common variety of andesite is a purplish, fine-grained rock with very prominent white feldspar phenocrysts commonly about 1 millimeter in length, showing striations. Greenish and purplish andesite breccias occur in lesser amounts. Fragments ranging in size from 5 millimeters to 3 or 4 centimeters are abundant in these rocks.

PETROGRAPHY

The green andesite contains phenocrysts of feldspar in an altered, fine-grained groundmass. The feldspar phenocrysts which comprise about 70 per cent of the rock are usually altered but even those showing the greatest change are visibly striated. Quartz is absent in most of the sections. Residual patches of epidote and calcite, commonly including grains of magnetite, probably represent former ferromagnesian phenocrysts. One of the fresher specimens contained the following minerals in approximately the amounts indicated: Andesine (Ab_6 An_4) 60 per cent, orthoclase 15 per cent, quartz 1 per cent, magnetite 1 per cent, titanite and apatite 1 per cent, epidote 12 per cent, calcite 5 per cent, chlorite and sericite 5 per cent.

The purplish andesite contains phenocrysts of feldspar, augite, hornblende, and small amounts of magnetite in a microcrystalline groundmass which is stained a brownish-red color with hematite dust. (See Fig. 2, Pl. 7). Although the groundmass is considerably altered, flow-structure is apparent. The feldspar phenocrysts average about 1 millimeter in length and 0.5 millimeters in width, and comprise about 50 per cent of the rock. A few rhombic-shaped feldspars with marked zoning occur here and there. The plagioclase phenocrysts, which have the composition of andesine (Ab_6 An_4) are

prominently twinned according to the albite and carlsbad laws and frequently contain numerous tiny inclusions. Orthoclase comprises less than 5 per cent of the feldspar. Phenocrysts of light green augite and hornblende with black reaction rims occur in less amounts.

Magnetite, titanite and zircon occur as accessory minerals, the first usually altering to limonite around the borders.

DACITE

GENERAL CHARACTER

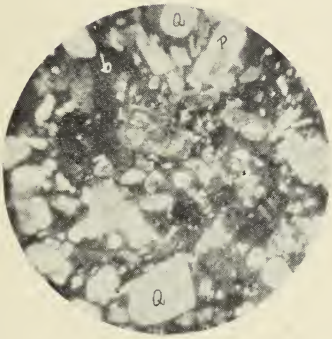
Dacite occurs in the Bannack district but not as abundantly as the andesitic rocks. The most common variety is a grayish-green, medium to fine-grained porphyritic rock. Feldspar, biotite, and quartz phenocrysts can readily be distinguished with the naked eye. Some breccias also apparently contained enough quartz to be classed as dacite but were not studied in thin section.

PETROGRAPHY

Phenocrysts of feldspar, quartz, biotite, hornblende and magnetite occur in a fine-grained groundmass (Pl. VI, 1). The phenocrysts comprise about 65 per cent of the rock. Striated andesine plagioclase ($An_4\,Ab_6$), averaging about 1 millimeter in length and 0.5 millimeters in width, comprise about 65 per cent of the phenocrysts. They are somewhat dusty in appearance due to alteration. The rounded quartz phenocrysts, which are clear and glassy, show corrosion and embayment. Quartz sometimes almost entirely surrounds lath-shaped feldspars and poikilitic inclusions of feldspar, magnetite and biotite are common. The average size of the quartz phenocrysts is about 0.5 millimeters. Orthoclase comprises less than 10 per cent of the phenocrysts. Biotite and hornblende, constituting less than 5 per cent of the phenocrysts are the predominant dark constituents. Magnetite, commonly showing alteration to limonite, is the commonest accessory mineral. It occurs disseminated through the groundmass and as square-shaped crystals about 0.2 millimeters across. Apatite and titanite occur also as accessory minerals. Calcite is abundant as a secondary mineral. Because of the abundance of quartz the rock is classified as a dacite.

RHYOLITE

Rhyolite is relatively rare in the region. It is commonly fragmental in structure and white or pink in color. A pink breccia is the most widespread (Pl. VI, 4). The fragments, contained in the breccia, frequently show flow structures, and range in size from 1



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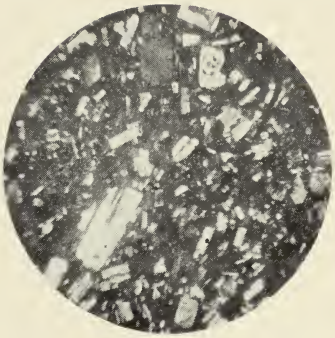

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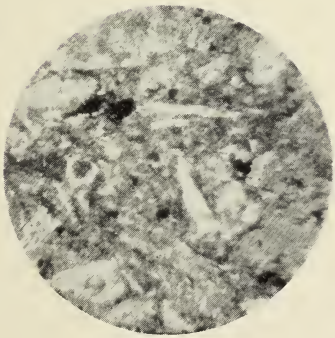

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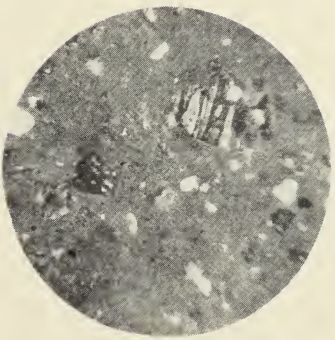

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PHOTOMICROGRAPHS OF EXTRUSIVE ROCKS FROM THE BANNACK DISTRICT.

1. Dacite porphyry showing phenocrysts of quartz (q), biotite (b), plagioclase (p). Polarized light. Magnification 7 times.
2. Andesite porphyry showing plagioclase phenocrysts in a microcrystalline groundmass. Polarized light. Magnification 7 times.
3. Tuff from lower portion of "Red Beds" showing glass shards. Ordinary light. Magnification 7 times.
4. Rhyolite tuff showing fragmental texture. Light colored mineral is quartz. Darker fragments are mostly rock material. Polarized light. Magnification 7 times.

millimeter to several centimeters. A white fine-grained lava with conspicuous phenocrysts of quartz and altered biotite occurs in lesser amounts. It contains small vesicles and solution cavities. A very fine-grained white rhyolite tuff occurs in some abundance. It contains some rounded pebbles of foreign material and in most places is noticeably banded.

BASALT

Basalt is rare. A few basaltic rocks were noted but because of their infrequent occurrence they were not studied in thin section. Winchell[25] mentions the occurrence of a basalt-capped mesa about 5 miles south of Bannack.

AGE OF THE VOLCANIC ROCKS

No evidence definitely fixing the age of the volcanic rocks was found within the region. It is quite probable that there were two periods of volcanic activity. The andesite rocks may have shared in the deformation of the region which, in part at least, pre-dated the intrusion of the granodiorite. The intense hydrothermal alteration of the andesite suggests that they may have been intruded by the granodiorite. These rocks may correspond in age with the andesitic rocks in the Butte and Helena regions which Knopf[26] has assigned to the late Cretaceous. The basalt in the Bannack region and to the south is probably of Tertiary age.

DEFORMATION

FOLDING

Several major folds are developed in the area and minor folding is pronounced. Immediately east of Bannack the sedimentary rocks have been folded into a broad overturned anticlinal dome. Intrusive rocks occupy the core of this dome and may have caused the increase in dip in their immediate vicinity. A series of well-developed folds occurs in the northern end of the region. Quadrant quartzite occupies the synclinal troughs and the older Madison limestones are exposed at the crests of the anticlines (Pl. III, 1). In the vicinity of the Kent Mine, about two miles northeast of Bannack, an anticlinal dome is exposed and its crest eroded.

Minor folding is pronounced in the vicinity of thrust faults, especially on the hanging-wall side (Pl. VII, 2). It is usually complex and can only be represented on the cross sections in a general way.

25. Op. cit. p. 50.
26. Knopf, Adolph: op. cit., pp. 23-29.

FAULTING

East of Bannack the Madison limestone can be seen resting discordantly upon folded "Red Beds". The discordance is due to overthrust faulting, the fault having a general northerly strike. The fault zone is present in the Blue Grass and Pioneer mines[27] and was observed in the main tunnel of the Ingersoll mine. This tunnel was run its entire distance (150 feet) in a white limestone gouge. In sec. 9, an outlier of blue Madison limestone rests upon the "Red Beds" and contains abundant fossils. It caps the high point just northwest of Bon Accord. Considerable evidence points to the fact that the thrusting was not limited to one surface but occurred along a number of surfaces. The fault exposed in secs. 9 and 14 is the best example of this minor faulting (Pl. VII, 2). Normal faults were observed throughout the district.

The thrust faulting at Bannack is of more than local interest because it probably belongs to the great system of overthrusting faults which extend at least from Canada on the north, well into Utah on the south.

The Philipsburg Quadrangle[28] north of the Bannack area, is traversed from north to south by an overthrust or zone of overthrusts bringing Algonkian rocks into contact with Carboniferous and Jurassic rocks. Still farther north, the Lewis overthrust, with a displacement of about 7 miles, brings Algonkin rocks into discordant contact with Cretaceous rocks.[29] The Bannack overthrust in Idaho, south of the Bannack area, has been described by Richards and Mansfield.[30] Rocks from Cambrian to Mississippian age have been thrust on Triassic to Cretaceous formations and involve vertical displacements of 8,000 to 12,000 feet or more while the horizontal displacement is estimated at not less than 12 miles.

ORE DEPOSITS

HISTORICAL SKETCH OF MINING

Although gold was found in Deer Lodge county as early as 1852, the first important discovery of metallic wealth in Montana was the discovery of placer gold at Bannack in August, 1862. Before the end of the year over 400 people had rushed to the new "diggings". However, after the discovery of the rich gulch near Virginia City, Montana, in 1863, placer mining was practically abandoned at Bannack until after the completion of the Smith and

27. Dunn, William, personal communication.
28. Emmons, W. H., and Calkins, F. C., op. cit. p. 146.
29. Willis, Bailey, Bull. Geol. Soc. American, vol. 13, pp. 305-352, 1902.
30. Richards, R. W., and Mansfield, G. R., Bull. Geol. Soc. America, vol. 23, p. 675, 1913. U. S. Geol. Sur. Bull. 577, pp. 34-38, 1914.

A. MADISON LIMESTONE OVERLYING FOLDED "RED BEDS."

B. MINOR FOLDING DEVELOPED ALONG FAULT IN THE S.W.¼ OF SEC. 9.

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Graeter ditch in 1866. This company furnished water to the miners at the high rate of 75c per miner's inch. This ditch proved inadequate to work the bench gravels, so the Bannack Mining and Ditch Company constructed a 30-mile ditch at a cost of $35,000; and shortly afterward, the Pioneer ditch, 10 miles long, was constructed to work the bench gravels north of Bannack. By 1870 two other ditches had been completed: White's ditch, which took water out of Grasshopper Creek to work the bars below Bannack, and, the Canyon ditch, also from Grasshopper Creek, to work the Bon Accord placers.

The construction of these ditches renewed the placer mining activities for awhile, but it was only a matter of time until all the suitable ground was worked over. The placer production gradually declined until the spring of 1895, when a gold dredge, the Fielding L. Graves, was launched near Bannack. This was the first successful gold dredge launched in the United States.[31] It was electrically operated and had a capacity of 600 yards per day. In the richest ground this dredge took out $22,000 in one week and $38,000 the following week.[32] The Molly A. Gibson, the second successful dredge, was launched in the fall of 1895, just north of the Excelsior mine. The A. F. Graeter was launched May 23, 1896. It recovered about $200,000 in the first year, which paid for itself and the placer ground on which it operated. A fourth dredge was launched at Bon Accord a short time later. The fifth dredge, the Coast, was built 2 or 3 miles below Bon Accord but capsized when it was launched.

The first quartz mine in Montana, the Dakota, was located in 1862. The claims were located according to the local mining rules and regulations of 1862[33], which provided that the claims be limited to 100 feet along the lode and 25 feet on either side. The numerous small claims and divers ownerships led to confusion, and inefficient mining. The Wadams, Excelsior, Wallace and numerous other gold properties were located shortly after the Dakota.

The first quartz mill was built in 1862-63, by Allen and Arnold to treat the Dakota ore. It was a 6-stamp mill, entirely hand-made, and was driven by water power. The first steam-operated stamp-mill, with 24 stamps, was built by Butterfield and Hopkins in 1864, at a cost of $25,000. Three other mills were built before 1870. The cost of treating ore in these mills was about $4 per ton. All these

31. Jennings, Hennen: The history and development of gold dredging in Montana. U. S. Bureau of Mines, Bull. 121, 1916.
32. This information was kindly furnished by Mr. F. L. Graves of Bannack.
33. Noyes, A. J.: Dimsdale's Vigilantes of Montana, p. 222, 1915.

mills have been dismantled. In 1914 a cyanide mill of 200 tons capacity was constructed by the Bannack Gold Mining and Milling Company. It ran only for a short period and has since been idle. A stamp-mill was built on the Hendricks property in 1920, and operated for about two years.

The silver mines of the Blue Wing mining district were discovered in 1864. Although rich, the ore was not free milling. Some of it was shipped to Wales for treatment, but after the construction of the smelters at Argenta and Bannack most of it was treated locally. In 1868 three smelters were in operation: one at Bannack, one at Argenta, and a third on Taylor Creek, between Bannack and Argenta. Eaton[34] estimates that the smelting cost was at least $38 per ton, and Keyes[35] estimates that ore of less value than $100 per ton could not be profitably smelted.

The mines at Bannack have been worked intermittently in recent years, largely by lessees, and have produced considerably from time to time. Thus within the last 15 years Mr. William Dunn has mined about $200,000 worth of ore and shipped about $100,000 from the old dumps.

PRODUCTION

The total production of the region including the yield in placer gold, lode gold, and silver is not accurately ascertainable but is estimated to be about $12,000,000. Mr. William Dunn,[36] who is probably most familiar with past production records, estimates the total placer production of the Bannack region to be roughly $8,000,000. Mr. Carl Hand,[37] who was associated with mining activities at Bannack, both as mine superintendent and private operator, for a number of years, estimates the lode gold production, excluding that of the Hendricks mine, to be over $2,000,000. The silver production, chiefly from the Blue Wing mining district, probably did not exceed $2,000,000.[38] Placer mining in the region is now insignificant, probably yielding not over $1,000 yearly, while lode production varies from a few thousands yearly to as much as $100,000, depending largely upon the activity of the lessees.

MINERALOGY OF THE ORES

Gold and silver minerals are the most important in the ores of the Bannack region, although minor amounts of lead, zinc and

34. Mineral Resources of the States and Territories west of the Rocky Mountains for 1868, p. 496.
35. Op. cit. Appendix, p. 55.
36. Personal communication.
37. Private report.
38. This figure is considerably less than Winchell's estimate, but is believed by the writer to be a reasonable one.

copper are produced. Practically all the gold has come from the Bannack mining district. The Blue Wing district has produced most of the silver.

ORE MINERALS

The following minerals which occur in the Bannack district are arranged according to Dana's classification:

Gold, native gold is found throughout the Bannack region. It occurs both in the placers and lode deposits at Bannack and is found in small amounts in the ores of the Blue Wing district.

Silver, native silver has been reported as occurring in the Golden Leaf mines and probably occurs associated with the silver ores of the Blue Wing district.

Stibnite, antimony sulphide, is found at the Del Monte mine, where it occurs as needle-like crystals in a quartz gangue.

Tetradymite, bismuth telluride, is found in the gold ores of the Bannack district. It is particularly abundant in the Excelsior and Gold Bug ores where it has been known as a gold telluride. In appearance it resembles graphite. Metallic gold can usually be seen scattered through it, even in hand specimens.

Galena, lead sulphide, is widely distributed but rarely occurs in amounts sufficient to constitute a valuable lead ore. A good grade of galena ore was encountered on the lower level of the Kent mine.

Argentite, silver sulphide, has been recognized in both the Bannack and Blue Wing districts.

Jalpaite, a finely disseminated mineral with microchemical reactions corresponding with those of jalpaite was noted in the ores from the Kent mine. Jalpaite is a copper-bearing silver sulphide.

Sphalerite, zinc sulphide, is found in considerable amounts in the silver ores of the Blue Wing district.

Covellite, copper sulphide (CuS), occurs in small amounts as a secondary mineral at the Kent mine.

Chalcopyrite, copper iron sulphide, is found in most of the sulphide ores in the Bannack region.

Pyrite, iron sulphide, is probably the commonest sulphide mineral in the Bannack region. It is found in all the mines.

Jamesonite, lead antimony sulphide, occurs at the Kent and New Departure mines.

Pyrargyrite, silver antimony sulphide, has been noted in the sulphide

ores at the Del Monte and Kent mines. It was an important ore mineral at the Del Monte mine.

Tetrahedrite, copper antimony sulphide, (gray copper), occurs in considerable amounts at the Kent, Del Monte and New Departure mines.

Polybasite, silver antimony sulphide, was noted in polished sections of the Del Monte ore.

Cerargyrite, silver chloride, (horn silver), is found in the oxidized silver ores of the Blue Wing district.

**Bromyrite,* silver bromide, and embolite, silver chloro-bromide, have been reported in association with cerargyrite, but their occurrence has not been proved positively in the oxidized ores of the Blue Wing district.

Stibiconite, yellowish antimony oxide, is found as an oxidation product in the antimony ores at the Del Monte mine.

Melaconite, black copper oxide, is found in the ores of the Golden Leaf mines. Considerable amounts of it occur in a stope near the collar of the Priscilla winze in the Golden Leaf mine.

Psilomelane, a small deposit of this hard black manganese dioxide occurs at the New Departure mine. Some of the material has been shipped as a manganese ore.

Smithsonite, zinc carbonate, is known to occur in the oxidized ores of the Kent and Del Monte mines.

Cerussite, lead carbonate, is a common mineral in the oxidized ores of the Blue Wing district. It is an important ore mineral at the Kent mine.

Malachite, the green basic copper carbonate, is a common oxidation product in nearly all of the mines of the region.

Azurite, the blue basic copper carbonate, was noted at the gold mines at Bannack and at the Kent and New Departure mines in the Blue Wing district.

Calamine, zinc silicate, was noted as drusy coatings and as aggregates of needle-like crystals in the oxidized ores of the Kent mine.

Chrysocolla, copper silicate, ranging in color from light green to dark brown, occurs in the oxidized ores of the Bannack mines.

Bindheimite, a hydrous antimonate of lead, is found as yellowish or greenish-yellow waxy and earthy material at the Kent and New Departure mines.

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*The time-worn myth of silver "bromides" dies hard. Unless the presence of bromine can be established beyond a doubt, it is safe to assume that these greenish-stained silver-bearing minerals are derived from argentiferous tetrahedrite, and are merely silver chloride colored by copper carbonate.—F. A. T.

Anglesite, lead sulphate, is found in the oxidized ores of the Blue Wing district. It is an important ore mineral at the Kent mine.

Caledonite, a basic sulphate of lead and copper, was noted as a light blue waxy material at the Kent mine.

Linarite, an azure blue basic sulphate of lead and copper, occurs in small amounts at the Kent mine.

Wulfenite, lead molybdate, occurs sparingly in vugs as orange-red crystals at the New Departure mine.

GANGUE MINERALS

Sulphur in the native form is found in the Golden Leaf mines where it occurs massive and as drusy coatings.

Quartz is the most wide spread and abundant gangue mineral. It is found in all of the mines in the region.

Hematite, the specular iron oxide, occurs as a primary mineral in the gold ores at Bannack. Red earthy hematite is found in the outcrops of the ores throughout the region.

Magnetite, magnetic iron oxide, occurs in considerable amounts in the contact metamorphic deposits in the Bannack vicinity.

Pyrolusite, the soft black manganese dioxide, is found in all of the oxidized outcrops of the Blue Wing district. It also occurs as needle-like crystals in veinlets cutting psilomelane at the New Departure mine.

Limonite, the name limonite is here applied to all of the brown earthy iron oxides of the district. It is the most widely distributed mineral in the oxidized outcrops.

Calcite, calcium carbonate, is one of the most common gangue minerals in the region. It is found in the ores of all the mines.

Siderite, iron carbonate, occurs as a gangue mineral in the ores of the Blue Wing district.

Rhodochrosite, manganese carbonate, was observed in the sulphide ores at the Kent mine.

Garnet, garnets are common gangue minerals in the gold ores at Bannack.

Vesuvianite, a basic silicate of calcium and aluminum, is found in the contact metamorphic deposits at Bannack.

Epidote, a dark green complex silicate, is a common mineral in the gold deposits at Bannack.

Chlorite, the fine-grained green mica is a common gangue mineral in the gold ores at Bannack.

Gypsum, hydrous calcium sulphate, is found in the Golden Leaf mines as a secondary mineral.

BLUE WING MINING DISTRICT

The Blue Wing mining district is in the northern part of the Bannack area (Pl. I). The ore bodies of this district occur predominantly as replacement veins[39] in limestone and granodiorite. Most of the production has come from the deposits in limestone. All the deposits in limestone lie close to the contact of the limestone with the granodiorite. The close proximity of the intrusive contact and the replacement silver deposits suggests the granodiorite as the source of the ore in the Blue Wing mining district.

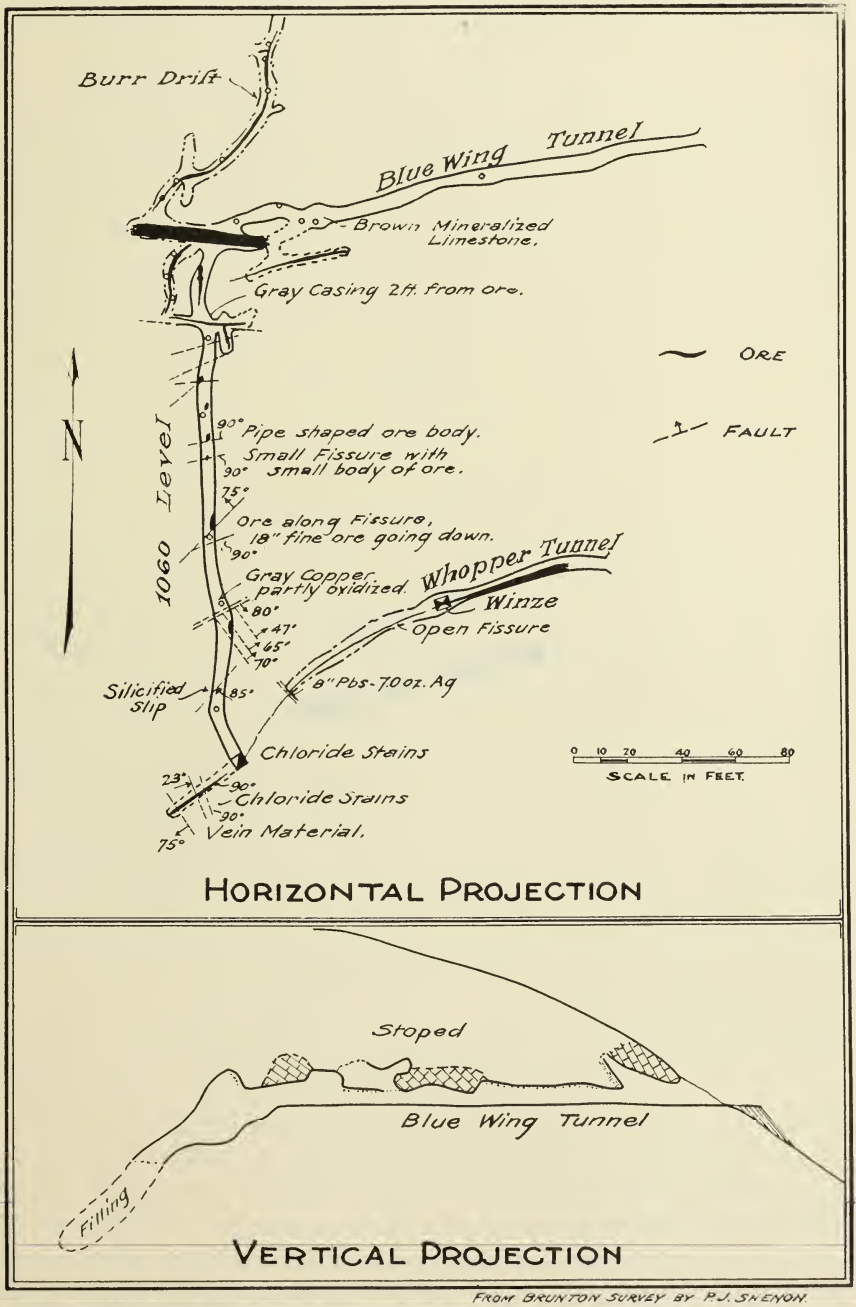
The ore minerals in the Blue Wing mining district include gold, silver, stibnite, galena, argentite, jalpaite, sphalerite, covellite, chalcopyrite, pyrite, pyrargyrite, tetrahedrite, polybasite, ceragyrite, bromyrite (?), stibiconite, pyrolusite, hematite, limonite, psilomelane, smithsonite, cerussite, malachite, azurite, chrysocolla, calamine, mimetite, bindheimite, anglesite, linarite and wulfenite. The commoner gangue minerals are calcite, quartz, rhodochrosite and siderite.

KENT MINE

The Kent mine is located near the head of Spring Gulch, about three miles northeast of Bannack. The claims lie within secs. 28 and 33, T. 7 S., R. 11 W., and are about one-half mile south of the old Bannack-Dillon stage road. The property comprises one unpatented and four patented claims.

The Kent veins were located in 1864[40] and were known as the Blue Wing, Kent, and Bannack Chief. These were the first silver deposits located in Montana. John F. O'Leary, who worked the mines successfully during the 'sixties and 'seventies, shipped the ore by ox-team to the Central Pacific railroad at Corrinne, Utah, thence by rail to San Francisco, and from there by water to smelters at Swansea, Wales. In the early 'eighties lessees mined ore worth $68,000 within a period of fourteen months. A short time later, Philip Shenon* acquired a two-thirds interest in the property. Mr. Shenon ran an 850-foot tunnel from the Edith claim into the hill between the Blue Wing and Kent. This adit, which is the main entry to the mine, intersected a body of lead-zinc ore near the contact between the intrusive and limestone which averaged 25 ounces in silver per ton. This sulphide deposit is known as the "blind lead". In 1910, S. P. Burr, operating under a bond and lease, exposed a

39. Lingren, Waldemar: Mineral Deposits, McGraw-Hill Pub. Co., N. Y., pp. 69, 604, 1919. Also Bull. Geol. Soc. Amer., vol. 36, pp. 247-262, 1925.
40. O'Leary, John F.: From a report written in 1908.
* Father of the writer, F. A. T.



MAP OF BLUE WING WORKINGS OF KENT MINE

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small body of ore in the Blue Wing workings which netted approximately $10,000. Mr. John O'Leary estimates the production of the Kent property to be approximately $750,000.

The ores of the Kent mine occur as shoots along fissures in white crystalline limestone and as veins in granodiorite but the deposits in limestone alone have been worked. The fissures in limestone strike N. 80 degrees E. and dip 70 degrees N. and all the deposits in limestone occur a short distance from the granodiorite contact. The Kent and Whopper ore bodies were tabular deposits along well-defined fissures. The Kent ore-body which raked to the west at an angle of about 20 degrees was the largest in the mine. The Whopper ore body was an irregular deposit along the Whopper fissure, and its downward extension has not yet been found. The Hayes and Ewing ore-shoot was a pipe-like deposit occurring at the intersection of the Blue Wing fissure with the contact of a white marble and a dense bluish-gray limestone (Pl. VIII). Above the tunnel a small seam of ore extended out along the fissure to the portal. The Burr ore shoot was a peculiar winding pipe extending away from the Hayes and Ewing ore body. The Kent and the Hayes and Ewing stopes average from 8 to 10 feet in width, but the Whopper was considerably narrower. The walls of the ore bodies are usually well defined although the ore is sometimes "frozen" to the walls. The limestone for several feet adjacent to the larger ore shoots is frequently altered to a chocolate-brown color and sometimes a gray clay-like casing is found next to the ore.

The veins in granodiorite have well-defined walls which are frequently slicken-sided. The ore in the Shenon tunnel, known as the "blind lead", is exposed by crosscuts for a distance of 170 feet. It strikes east and dips about 30° to the south. The ore band is associated with two or three feet of gouge impregnated with pyrite on the foot-wall side. The ore itself is cut by slicken-sided fractures, the result of post-mineral movement. The relationship between the veins in granodiorite and those in the limestone could not be ascertained because of the condition of the old workings.

The chief gangue minerals of the ores in limestone are quartz and calcite and the ore minerals include galena, tetrahedrite, jamesonite, sphalerite, covellite, pyrite, jalpaite (?), cerargyrite, bindheimite, linarite, caledonite, cerussite, anglesite, malachite, azurite, chrysocholla, smithsonite, calamite, limonite, and manganese oxides. Much of the ore, particularly in the Kent vein, is soft porous material predominantly brown in color, but containing green and yellow

"splotches" of lead, copper, and silver minerals. The ore from the Blue Wing and Whopper veins is predominantly greenish and yellowish in color, usually well indurated, and sometimes waxy in appearance. Because the harder ore is sometimes "frozen" to the walls skillful mining is required to prevent heavy losses.

Residual remnants of sulphide, known locally as "black metallics", occur in the oxidized ore. Pyrite and galena are the oldest minerals in the residual patches. The pyrite is partly oxidized to limonite and the galena shows typical alteration to anglesite along cleavage planes (Pl. IX, 2). The tetrahedrite and jalpaite (?) account for the very high silver content of the sulphide patches. The jalpaite (?) is commonly seen replacing pyrite. Covellite in turn replaces jalpaite (?), showing splendid intergrowths and replacement borders (Pl. IX, 1). Although the evidence is not complete it is believed that the jalpaite (?) and covellite are both supergene minerals. Neither are known in the sulphide ore of the "blind lead."

The sulphide ore in the granodiorite is in a gangue of quartz and calcite. Galena, sphalerite and pyrite are the commonest ore minerals and chalcopyrite was noted as inclusions in sphalerite. Pyrargyrite is visible locally and probably accounts for the high silver content shown in some of the assays. Both gangue and ore minerals have been brecciated and re-cemented but the galena is sometimes deformed without fracturing. The sulphide ore shows no oxidation, and secondary enrichment only locally. In 1908 lessees made a shipment of the "blind lead" ore from near the contact with the limestone which gave the following smelter returns:

Gold	Silver	Lead	Zinc	Silica	Iron	Sulphur
0.09 oz.	29.7 oz.	1.5%	3.6%	40.2%	5.8%	11.8%

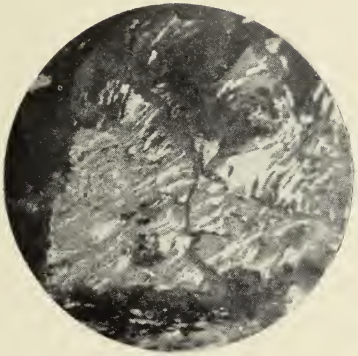
Samples from the ore-body in No. 2 crosscut 230 feet east of the limestone contact gave the following assays:

Silver	Lead	Zinc
17.4 oz.	30.1%	8.5%
20.0	20.0	—
38.5	32.4	19.0

The veins in the limestone which were readily seen at the surface have been mined at a handsome profit, nevertheless, little search has been made for new deposits. The most favorable place to prospect for high-grade ore is along the contact of the white marble and the bluish-gray limestone.

DEL MONTE MINE

The Del Monte mine is in sec. 28, on the old Bannack-Dillon stage road, about a mile northwest of the Kent mine. The property



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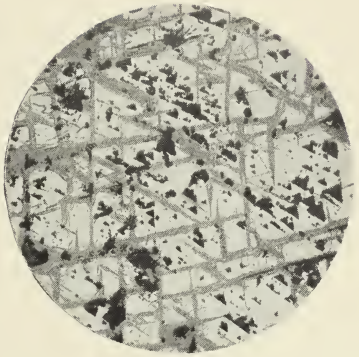

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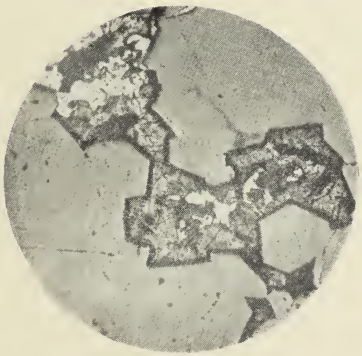

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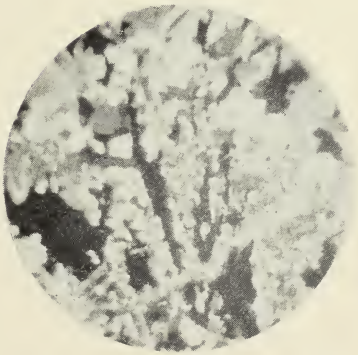

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PHOTOMICROGRAPHS OF ORES FROM THE KENT AND DEL MONTE MINES

1. Covellite (dark gray) replacing jalpaite (?) (white). Fracture filled with quartz. Magnification 540 times.
2. Galena (white) being replaced along cleavage planes by anglesite (gray). Black spots are holes. Magnification 50 times.
3. Tetrahedrite (white) partly replaced with polybasite (etched with cyanide). The gray mineral with euhedral outlines is quartz. Polished section. Magnification 14 times.
4. Stibnite (black) in quartz cut by a veinlet of later quartz. Thin section. Ordinary light. Magnification 7 times.

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comprises six patented claims, and is owned by the West Butte Mining Company.

Very little was learned of the history and production. Some early-day shipments were made[41] but records of the returns are not available. Lessees who took out considerable ore in the late 'nineties are said to have netted a profit. One of the cars shipped averaged over 500 ounces in silver per ton. Since these lessees sank a shaft to a depth of over 250 feet, and handled considerable water, besides doing a good deal of drifting, it is estimated that they must have taken out at least $30,000 and probably not over $50,000. The West Butte Mining Company purchased the property from the Graves estate of Bannack, in 1922 and, after cleaning out and retimbering the Del Monte shaft, ran a number of prospect drifts, chiefly on the upper levels. Prospecting was abandoned after a year's work, and the property has since been idle.

The underground workings[42] with the exception of a few tunnels and open cuts, are all driven from the Del Monte shaft, which reached a depth of 253 feet. At present the shaft is full of water below a depth of 50 feet.

The ores in the Del Monte mine occur chiefly in well-defined veins in granodiorite which strike about N. 80° E. and dip at steep angles to the south. Veins in the limestone usually have a low silver content but some contain small deposits of high-grade antimony ore. According to F. M. Wichman[43] faulting has been extensive in the neighborhood of the Del Monte mine. The faults trend in all directions but the northerly and northeasterly ones are the most prominent.

Two veins in the granodiorite have been mined, the Del Monte and the Bonaparte. The Bonaparte is the larger but is lower grade than the Del Monte vein, and is said to assay from 20 to 40 ounces in silver per ton. It is about six feet wide on the surface. The Del Monte vein ranges in width from 4 to 14 inches on the bottom level and averages 60 ounces of silver per ton. Some assays run as high as 450 ounces.

Near the surface these veins are much oxidized and are filled with brownish to black porous material consisting largely of quartz with oxides of manganese and iron. Casts of the original minerals are plainly visible. The sulphides appear about 50 feet beneath the surface and in the lower levels no evidence of oxidation is visible Sphalerite, galena, chalcopyrite, pyrite, polybasite, tetrahedrite and

41. Raymond, R. W.: Mineral resources west of the Rocky Mountains for 1872, 1873, and 1874.
42-43. Wichman, F. M.: Letter of May 17, 1925.

pyrargyrite occur in a gangue of calcite, rhodochrosite and quartz (Pl. IX, 3).

Small deposits of high-grade antimony ore occur on the Francis H. claim along vertical fissures which strike N. 60° E. in crystalline limestone. Stibnite is found in quartz gangue (Pl. IX, 4), and is associated with about two feet of a reddish-brown gouge. Slickensided fractures cutting the stibnite give evidence of post mineral movement.

NEW DEPARTURE MINE

The New Departure mine is situated about 16 miles southwest of Dillon, in the NW.¼ of sec. 26. The property comprises seven patented claims but the Signal and Quien Sabe produced all the ore. The property was located in 1871 by George W. Stapleton[44] who sold it to Lawrence A. Brown and Joshua E. Clayton in 1880 for the sum of $2,500. Brown purchased Clayton's interest seven years later for $3,500, and operated the mine continuously until the time of his death in 1905. The mine was then sold to the New Departure Mining Company for $50,000. This company operated for two years, having as many as forty miners working at one time. The property was then operated by lessees until 1918, when it was sold to O. M. Best of Dillon. John Coppin of Dillon worked it under a bond and lease agreement until 1928, when it was sold to J. L. Templeman of Butte. The mine is credited with a production of over a million dollars.

The ore bodies at the New Departure mine, which strike easterly and dip south, occur chiefly along fractures in massive bluish-gray Madison limestone. Some of the largest deposits are found along the intersections of fractures. The Farrell stope rakes down the intersection of two fractures. Intersecting northwest and northeast fractures are also responsible for the large ore body at the head of the incline in the Homeside tunnel. The ore shoots commonly terminate on the lower side of flat slips which are usually slickensided and striated by movement. Thus in the Badger workings the ore which stood at an angle of about 45° flattened and pinched out after reaching a flat slip. Some large ore bodies have been mined just beneath the slips, after the ore shoot flattened.

Cerargyrite, cerussite, bindheimite and other oxidation products with residual patches of sulphides composed chiefly of sphalerite, galena, and tetrahedrite occur in a gangue of quartz and calcite. Argentite (?), smithsonite, anglesite, malachite, azurite, gyp-

44. Historical date was supplied by John Coppin of Dillon.

sum and oxides of manganese and iron occur in lesser amounts, and assays indicate the presence of gold. Wulfenite occurs in small amounts.

A small deposit of high-grade manganese ore occurs just below the Stapleton tunnel. It strikes northeast and dips to the south. Psilomelane is cut by small veins filled with fibrous pyrolusite. A small deposit of oxidized gold ore said to carry $10 per ton in gold was found just north of this deposit.

HURON MINE

The Huron mine is just north of the Kent and comprises seven claims all of which are in sec. 28. The claims were located in the 'sixties by a man named Batchelor who mined considerable ore, some of the early shipments being sent to Swansea. The property was later acquired by John Costello who sold a half interest to Frank Sinnott in 1910. The latter became the sole owner after Costello's death. Mr. Sinnott estimates the total production to be about $30.000.[45]

The deposits at the Huron mine occur as replacements along fissures in white crystalline limestone. The principal fissures strike east and dip about 70° to the south. The ores are similar to those of the Kent mine. Cerargyrite with patches of residual sulphides occur in a gangue of quartz and calcite.

POMEROY MINE

The Pomeroy mine is northwest of the Del Monte mine and comprises three claims. The property was located in the 'sixties and produced considerable ore in the early 'seventies.[46] The main workings consist of an incline shaft with open stopes which reach the surface. The ore which occurs in a bluish-white limestone is in well-defined fissures which strike N. 80° E. and dip 60° N. The chief ore mineral is lead carbonate which carries silver. A red gouge varying in thickness from 2 to 4 feet is associated with the ore.

RANDALL MINE

The Randall mine adjoins the Kent mine on the south. It includes one claim and is owned by Mr. H. C. Paddock of Bannack. The property was located in the 'sixties and has produced considerable ore which has been mined chiefly for its silver content, although considerable galena is associated with it. The ore occurs as replacement deposits along fissures in a white crystalline limestone which strike east. The shoots terminate against a massive bluish-gray limestone.

45. Sinnott, F. F., Personal communication.
46. Raymond, R. W., Mineral resources west of Rocky Mountains for 1872, p. 267.

SILVER STAR MINE

The Silver Star mine is in SW.¼ of sec. 33, T. 7 S., R. 11 W., just west of the limestone-granodiorite contact. It is owned by the Monroe Mann estate. The ores occur as replacements in veins which strike N. 50° W. and dip 60° to the south and along bedding planes in flat-lying Madison limestone. The ore is chiefly oxidized material and is reddish-brown in color with occasional green and yellow patches of copper and silver minerals.

INGERSOLL MINE

The Ingersoll mine lies just south of the Silver Star in sec. 4, T. 8 S., R. 11 W. and includes three claims. It is owned by the Amede Bessette estate of Bannack. The property was discovered in the 'sixties and is credited with considerable early-day production, from open cuts and tunnels. In 1912 Phillip Lonergran, working under a bond and lease, sank a winze to a depth of about 200 feet. This winze crossed the contact between the limestone and granodiorite and was extended into the granodiorite for some distance.[4] A tunnel 150 feet in length connects the Lonergran winze with the surface. This tunnel was driven its entire length in a white limestone gouge. The ore deposits occur as replacement veins in a white limestone and strike east. The ore minerals which occur in a quartz and calcite gangue include cerussite, cerargyite, bromyrite (?), and malachite.

CHARTER OAK MINE

The Charter Oak mine, which is south of the Ingersoll, was located in the 'sixties and has produced considerable ore. It is owned by Foy Herr of Bannack. The ore occurs as replacement veins in a white crystalline limestone and includes oxidized silver and lead minerals in a quartz and calcite gangue.

WHEAL ROSE MINE

The Wheal Rose property is in sec. 27, T. 7 S., R. 11 W., and is owned by Archie Gibson and the Graves' estate of Bannack. It is credited with some production. The ore occurs along fissures in Madison limestone which strike east. The ore minerals include cerargyrite and cerussite in a gangue of quartz and calcite.

IRON MASK MINE

The Iron Mask mine is in the SW.¼ of sec. 28, T. 7 S., R. 11 W. Little was learned of the history and production, although it is known that ore was shipped in the early days. The main entrance is a shaft which is said to have reached a depth of 200 feet. The ore is in well-defined veins in granodiorite which strike east. Near

the surface the ore is composed largely of black porous material consisting predominantly of quartz and calcite with oxides of manganese and iron. Sulphides are reported in the lower workings. On the surface the Iron Mask vein resembles those of the Del Monte, but no specimens were secured from the lower levels.

BANNACK MINING DISTRICT

The Bannack mining district is in the southern part of the Bannack area (Pl. 1). The ore deposits are at or near the contact between granodiorite and limestone and occur chiefly along or near the apex of apophyses (granodiorite outliers) which extend into the limestone. Well-defined fracturing appears above and in front of the apophyses, as illustrated by the mineralized fractures in the Excelsior mine and in the Dollar winze and Green raise of the Wadams mine. The fact that ore bodies are present along or at the apexes of the apophyses suggests that the apophyses were intruded along zones of weakness or that their intrusion caused the fracturing, which permitted ready access to mineralizing solutions. Although some rich deposits distant from the contact have been mined, the largest and most important ones occur as irregular bodies in limestone near the contact with the granodiorite. These deposits which are almost entirely oxidized in some of the mines, are found in greater abundance on the limestone side of the garnet zones. According to Umpleby[48] this relationship is a general one. Since fractures containing ore were observed cutting both limestone and garnet rock it is believed that the ore minerals were introduced after the garnetization. Bodies of magnetite and some pyrite and chalcopyrite were observed in the garnet zone. Lindgren[49] states that the silicates and magetite are earlier than the sulphides in contact deposits but that the periods of deposition overlap. The presence of garnet, vesuvianite and certain other minerals suggests that the deposits at Bannack were formed under conditions of high temperature and pressure[50] although specularite is present the favorable temperature for the formation of which in contact deposits is supposed to be about 490°.[51]

The ore minerals in the Bannack mining district include: native gold, tetrahedrite, argentite, cerargyrite, tetradymite, galena, cerussite, anglesite, sphalerite, chalcopyrite, tenorite, chrysocolla, azurite, melanconite, native sulphur, pyrite, specularite, magnetite, iron and

47. Sinnott, F. F.: Personal communication.
48. Umpleby, J. B., Univ. of Calif. Pub. in Geol., p. 25, 1916.
49. Lindgren, Waldemar: Mineral deposits, p. 718, McGraw-Hill Pub. Co., N. Y., 1919.
50. Emmons, W. H.: Principles of Economic Geology, p. 44. McGraw-Hill Pub. Co., N. Y., 1918.
51. Butler, B. S.: Economic Geology, vol. 10, p. 400, 1923.

manganese oxides. The gangue minerals include quartz, calcite, chlorite, garnet, siderite, epidote and vesuvianite.

THE BANNACK GOLD MINING AND MILLING COMPANY

The Bannack Gold Mining and Milling Company owns 14 lode claims and five placer claims in the Bannack mining district. Most of the production has come from the Excelsior, Blue Grass, and the Golden Leaf group, (which includes the Wadams, Wallace and Golden Leaf claims). All of the claims were located in the 'sixties and 'seventies, most of them under the early-day mining regulations which provided that claims be limited to 100 feet along the lode and 25 feet on either side. All have since been relocated in accordance with the Federal laws. Philip Shenon, who operated the mines for a number of years, sold the properties to the Golden Leaf Co., Inc., in the 'nineties. This company in turn sold to the Great Western Mines & Exploration Co., and the latter sold to the present owners in 1910. The Bannack Gold Mining and Milling Co. did considerable exploration work and constructed a 200-ton cyanide mill. This mill operated for but a short time. In 1930, the I. B. Mining Co. was operating the Golden Leaf group under a bond and lease agreement.

EXCELSIOR MINE

The Excelsior mine is near the eastern border of the granodiorite intrusive. The ore shoot has been mined to a depth of about 300 feet and has produced approximately $300,000.[52] The old shaft is now inaccessible. The Excelsior ore body occurred at the contact between crystalline limestone and granodiorite; at the apex of a granodiorite aphophysis. The limestone granodiorite contact at the mines strikes N. 35°W. and dips about 45°W. The stope at the tunnel level extends for about 30 feet along the contact and is about 8 feet in width. Intense garnetization had taken place near the contact. The garnet is clear citron-brown in color, in contrast to that in the Golden Leaf mine, of a dull reddish-brown color. Coarse crystalline calcite and specularite are associated with the garnet. The gold is either free or in tetradymite and is found in a light green gangue composed chiefly of calcite, chlorite, garnet, specularite and some quartz. The ore shoot occurring chiefly on the limestone side of the garnet zone was offset to the southwest by a series of step faults[53] in the lower workings.

52. Hand, Carl: Private report.
53. Dunn, William: Personal communication.

GOLDEN LEAF GROUP

The Golden Leaf group, including the Wadams, Wallace, and Golden Leaf claims, is at the western border of the granodiorite contact. The mines are all connected by raises and ore can be delivered to the mill from any of the workings through the tunnel known as the Priscilla level. The difference in elevation between

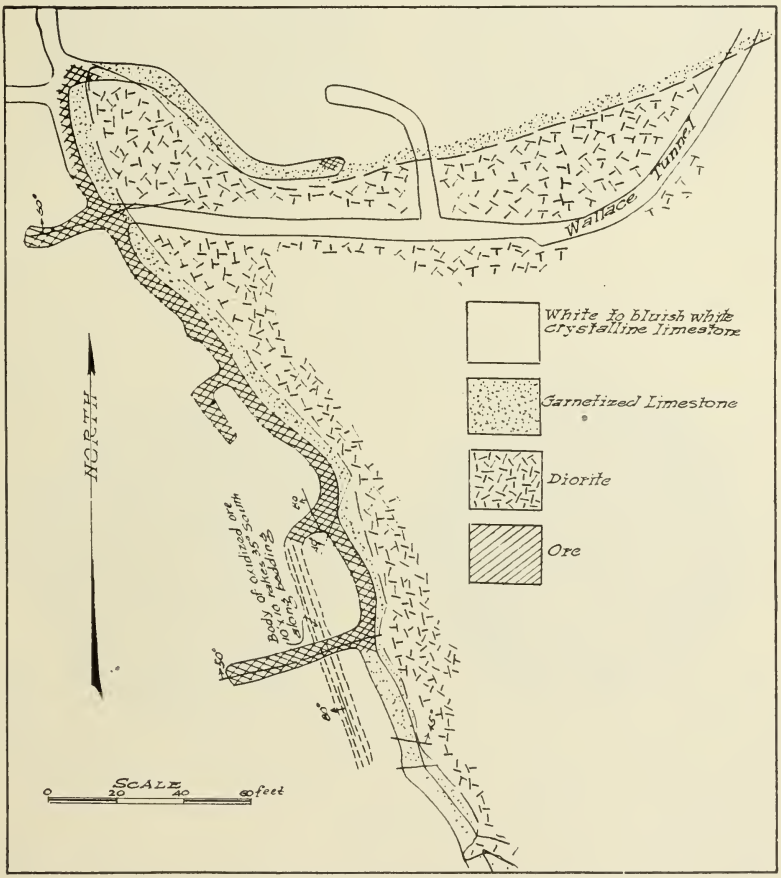

FIGURE 2. MAP SHOWING INTRUSIVE RELATIONS ON WALLACE LEVEL OF WADAMS MINE.

the Priscilla level and the upper workings of the Wadams mine is about 475 feet. The Dunn level, which is reached through an inclined winze is about 140 feet below the Priscilla level. Mr. Hand estimates the production of the Golden Leaf group to be about $1,320,000.[54]

The ore deposits are in a white or bluish-white crystalline lime-

54. Hand, Carl: op. cit.

stone at or near the contact with the granodiorite. Some of the best deposits occur along apophyses which extend out into the limestone. The deposits in the Wadams and Wallace mines are of this type (Fig. 2). The limestone is usually intensely garnetized near the contact with the granodiorite. The ore, which lies predominantly outside of the garnet zones, is almost entirely oxidized in the upper levels but the sulphides become more prominent in the lower levels. A large body of sulphide ore, about 15 feet wide, consisting largely of pyrite with lesser amounts of chalcopyrite, occurs in an intensely garnetized limestone in one of the crosscuts off the Priscilla level. The relative insolubility of the garnet gangue may account for the fact that these sulphides are quite fresh, although ore bodies in limestone on the same level are highly oxidized. Chalcopyrite and pyrite occur on the Dunn level in a dark green gangue composed largely of calcite and chlorite with lesser amounts of quartz, epidote and specularite (Pl. X, 4). Native gold with calcite was observed along fractures in the chalcopyrite (Pl. X, 3). Partly oxidized galena ore carrying silver occurs on the Priscilla level and deposits of magnetite were noted in several places along the limestone-diorite contact.

The ore minerals include native gold, tetrahedrite, chalcopyrite, malachite, azurite, chrysocolla, tenorite, galena, cerussite, anglesite, sphalerite, smithsonite, native sulphur, pyrite, specularite, magnetite, limonite, and manganese oxides.[55] The gangue minerals include calcite, quartz, siderite, garnet, epidote and vesuvianite.

BLUE GRASS AND GOLD BUG MINES

The Blue Grass mine is owned by the Bannack Gold Mining and Milling Company and the Gold Bug is owned by the Graves' estate of Bannack. The claims include a number of the earliest locations in the Bannack district. The Gold Bug embraces the original Dakota locations. Mr. Hand estimates the production of these properties to be about $550,000.[56]

The ore deposits are at or near the contact of a white crystalline limestone with a small tabular body of granodiorite. The limestone, which is intensely garnetized near the contact, contains abundant specularite. The ore is found predominantly outside of the garnet zone. These deposits occur in a region of minor folding and faulting. Gold in a quartz and calcite gangue or in tetradymite, (Pl. X, 1 and 2), is the most important metal but assays show the presence of silver. In 1925 Mr. Austin Hale opened a pipe-like

55. Shenon, P. J.: Gold at Bannack, Montana, Eng. & Min. Jour., vol. 123, p. 326, 1927.
56. Hand, Carl: op. cit.

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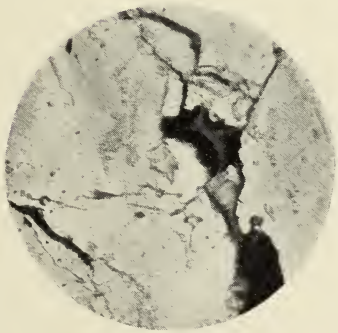

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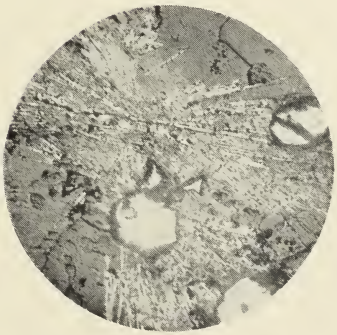

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PHOTOMICROGRAPHS OR ORES FROM THE BANNACK DISTRICT, MONTANA.

1 and 2. Native gold (white) in tetradymite (gray) showing tendency of the gold to follow parting planes. Tetradymite etched with nitric acid. Note structures developed by etching. (Gold Bug mine.) Magnification 14 times.

3. Gold (white) occurring along fracture in chalcopyrite (light gray). Surface etched with nitric acid. Calcite associated with the gold along fracture (black) was removed by the acid. (Dunn level, Golden Leaf mine.) Magnification 110 times.

4. Specularite (with radiating structure) in quartz (dark gray) terminating against pyrite. (Dunn level, Golden Leaf mine.) Magnification 14 times.

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deposit of granular pyrite which carried about $30 in gold, and in 1927 some work was done by C. W. Stalling. This deposit strikes N. 50° W., and rakes to the north at an angle of about 25 degrees.

HENDRICKS MINE

The Hendricks mine is about a quarter of a mile south of Bannack and on the opposite side of Grasshopper Creek. Two claims are included in the group, the Hendricks and the Suffield. Although the property was first located during the early days of Bannack, little ore was produced until 1918, when the Bannack Mining and Milling Company, operating under a bond and lease, put up a 5-stamp, amalgamation mill. A small ball-mill, a classifier and two cyanide tanks were added in 1919. In 1920 a new 10-stamp mill was built. It contained a ball-mill, a classifier, two agitators, four thickeners and six cyanide tanks and had a capacity of 50 tons in 24 hours. This mill was closed down in 1921. The underground workings include about 1,500 feet of drifts and one 50-foot winze. The property is now owned by the Graeter Park Realty Company of Dillon.

The ore occurs as shoots along bedding planes in limestone of Madison age which has undergone considerable minor folding. The ore of milling grade was in six different shoots within a distance of 200 feet, although the mineralization was continuous throughout.[57] Only one of the ore bodies came down as far as the working level. The shoots raked about 7° N. and dipped from 65° W., to less than 20° W., depending upon the bedding of the limestone. Ore occurred along at least two different bedding planes. The wall rock next to the ore bodies is considerably altered and some gouge was noted along bedding planes. Altered garnet was observed in the wall rock of one stope but no intrusive rocks are known underground. The ore is almost entirely oxidized and because of the oxidation about 50 per cent of the gold was saved by amalgamation.

C. W. Stallings estimates the total production of the property at $40,000.

PLACER DEPOSITS

The first important placer deposits discovered in Montana were those at Bannack in 1862. They produced $600,000 within the first year. Although some of the bench placers have been worked, the most productive were those in the stream bed of Grass-

57. Stallings, C. W.: Personal communication.

hopper Creek or along tributary gulches. Mr. Dunn[58] estimates the total placer production of the Bannack district to be about $8,000,000 distributed as follows:

Bannack Creek Placers—6,000,000 yd. @ $1 per yd.	$6,000,000
Bannack Gulch and Bench placers—4,000,000 yd. @ 30c per yd.	1,200,000
Bon Accord Placers—3,000,000 yd. @ 30c per yd.	900,000
Total	$8,100,000

Winchell estimates that Grasshopper Creek produced $3,000,000 in gold during the 'sixties.

The lode gold deposits are undoubtedly the source of the placer gold since no valuable deposits are found in Grasshopper Creek above Bannack and the gold content decreases downstream.

58. Dunn, William: Personal communication.

THE ARGENTA AREA

GENERAL GEOLOGY

CHARACTER AND DISTRIBUTION OF THE ROCKS

The prevailing rocks in the Argenta area are sedimentary. Consolidated sediments ranging in age from Algonkian to Pennsylvanian are found in the region, and Permian and Mesozoic rocks and Tertiary "Lake Beds" have been described in the Melrose and McCarthy Mountain areas, which are situated a few miles northeast of Argenta.[59] The unconsolidated rocks in the Argenta area include terrace gravels and glacial moraine.

The total outcrop of intrusive igneous rocks aggregates hardly more than one square mile and but few isolated outcrops of extrusive rocks are exposed within the map limits. This is in sharp contrast with the Bannack area where extrusive rocks prevail. Quartz monzonite, granodiorite, andesite porphyry, and dacite porphydy occur as intrusives and trachyte and rhyolite are the predominating extrusive rocks. The distribution of the various rocks is shown on the geologic map comprising Plate 1.

ALGONKIAN SYSTEM

SPOKANE FORMATION

The rocks assigned to the Spokane formation crop out for several miles along the crest of an anticlinal fold which strikes about N. 25° E. Only the uppermost part of this formation is exposed and consists of shales, quartzitic sandstones and at least one well-defined conglomerate bed. The shales are thin-bedded and fissile and characteristically have a high luster along the parting planes. The color is predominantly dark red, but beds of pale olive-green are abundant. Dark or brick-red colors prevail in the sandstones which show well-preserved ripple marks and mud cracks (Pl. XII). On the steeper slopes the top of the Spokane formation is difficult to delineate because of the thick talus of Flathead quartzite and, in other places, because of the difficulty in distinguishing the lower beds of the Flathead quartzite from similar appearing beds in the Spokane formation.

The rocks beneath the Flathead quartzite have been correlated with the Spokane formation, described by Calkins in the Philipsburg quadrangle, because of the marked resemblance to them and

59. Richards, R. W. and Pardee, J. T.: U. S. Geol. Sur. Bull. 780, pp. 1-32.

because of their position directly beneath the Flathead quartzite. No estimates have been made of the thickness of these beds in the Argenta district owing to the incomplete exposures, but Calkins estimates the formation to be over 10,000 feet thick in the vicinity of Philipsburg.*

CAMBRIAN SYSTEM

Two lithologically different formations have been tentatively assigned to the Cambrian system. The lower member is correlated with the Flathead quartzite because of its lithologic similarity to that well-defined horizon and because of the stratigraphic sequence of dark-red fissile shales and quartzitic sandstones beneath the vitreous pink and white Flathead quartzite in other parts of southwestern Montana.

The beds above the Flathead quartzite are comprised principally of gray sandy limestone. They are termed the Tilden formation in this report and are tentatively assigned to the Cambrian system. No angular discordance was noted between the Flathead quartzite and the Tilden limestones, where these beds were known to be in normal contact, although folding and faulting have caused a marked apparent non-conformity in several places. The Tilden limestone has about the same position in the stratigraphic column as the Gallatin formation of the Three Forks region[60] and the beds embraced by the Silver Hill, Hasmark, and Red Lion formations of the Philipsburg quadrangle.[61] The absence of shales at the top of the Flathead quartzite and throughout the Tilden formation is, however, in marked contrast with the Three Forks and Philipsburg regions where shales make up a considerable part of the Cambrian system.

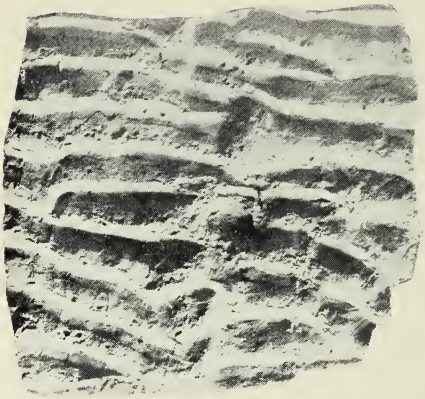
FLATHEAD FORMATION

The beds assigned to the Flathead formation are largely pink to red medium-grained quartzite. The darker colors predominate toward the bottom of the formation and, in general, the grain size increases. The bedding is distinct, the beds usually being several feet thick. Some indurated conglomerate beds occur interbedded with the quartzite. One well-defined conglomerate horizon is exposed near the base of the formation and another pebbly quartzitic sandstone, composed largely of rounded quartz grains from one to 5 millimeters in diameter, occurs 60 feet below the top of the formation.

* Emmons, W. H. and Calkins, F. C.: U. S. Geol. Sur. Prof. Paper 78, p. 45, 1913.
60. Peale, A. C.: U. S. Geol. Sur. Geol. Atlas, Three Forks folio (No. 24).
61. Emmons, W. H., and Calkins, F. C., op. cit.

A. GLACIAL MORAINE AT THE MOUTH OF RATTLESNAKE CREEK CANYON IN SEC. 15.

B. STEEPLY INCLINED LIMESTONE BEDS IN THE N.E.¼ OF SEC. 34.



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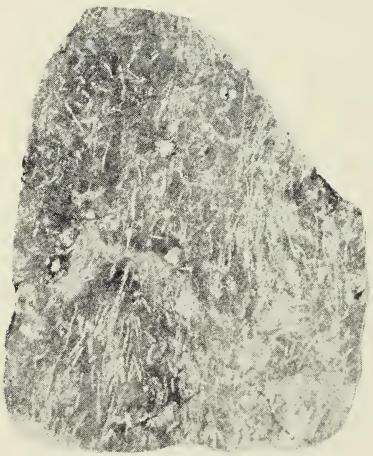

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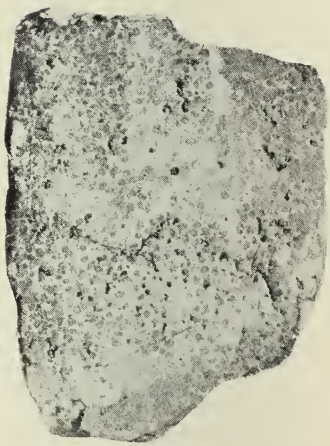

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1. Current ripple marks, characteristically developed in the quartzitic sandstone beds near the top of the Spokane formation. (1/6 natural size.)
2. Mud cracks from near the top of the Spokane formation. (1/3 natural size.)
3. Oolitic limestone from near the top of the Tilden formation. (3/5 natural size.)
4. Black magnesian limestone with twiglike bodies from base of Ermont formation. (1/3 natural size.)

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The bottom limit of the Flathead formation could not everywhere be accurately fixed because of the resemblance of some of the lower beds to some of the upper beds of the Spokane formation. The top of the formation is, however, very definite where it is in contact with Tilden limestone. The maximum thickness of the Flathead formation in the Argenta district is believed to be about 500 feet.

TILDEN FORMATION

The Tilden formation which lies directly above the Flathead quartzite is composed principally of gray to pinkish-gray sandy limestone. The more sandy beds occur near the base. Several of the most important ore deposits of the Argenta region occur in this formation. It is best exposed northwest of the Ermont mine where the following section was measured:

Section of Tilden formation in canyon northwest of Ermont mine

	Feet
Black thin-bedded Devonian limestone	
Muddy-colored sandy limestone. Beds 1 to 4 feet thick. Oolitic limestone bed, 8 inches thick, 10 feet up from base	102
Light-gray thin-bedded sandy limestone, Weathers buff	12
Massive crystalline bluish-gray sandy limestone	190
Fine-grained pinkish-gray limestone. Weathers tan	10
Gray sandy limestone	20
Thin-bedded white siliceous limestone	12
Gray sandy limestone with 6 outstanding beds. Mostly massive. Pebbly limestone at base contains angular quartz fragments mostly 5 millimeters across	75
	421
Flathead formation.	

No fossils were found in the Tilden formation at Argenta. Trilobite remains and other fossils have been found, however, in the Upper Cambrian beds of the Three Forks region[62] and a number of fossils have been collected in the Philipsburg district.[63]

A sill of dark green andesite porphyry closely parallels the contact between the Flathead quartzite and the Tilden formation for some distance north of Rattlesnake Creek.

DEVONIAN SYSTEM

ERMONT FORMATION

The rocks assigned to the Devonian system include a series of limestone beds about 1,500 feet thick. This formation is termed the Ermont formation in this report and correlates fairly well with the Jefferson formation of the Three Forks region[64] although no shale beds corresponding in position with the Three Forks shale are present in the Argenta district. Mr. George H. Girty of the

62. Peale, A. C.: op. cit.
63. Emmons, W. H. and Calkins, F. C.: op. cit., p. 63.
64. Peale, A. C.: op. cit.

United States Geological Survey identified Devonian fossils from near the top of the formation. Cup corals have since been found in the basal beds just south of the Coolidge mine.

The color contrast between the Ermont beds and the underlying Tilden beds clearly marks the base of the Ermont formation. In addition, the basal beds contain twiglike bodies that give the rock a peculiar mottled appearance (Pl. XII, 4). The top of the Ermont formation is not definite but was fixed at a cherty horizon in rocks that resemble the Madison formation. Devonian fossils were found 230 feet below this horizon and Madison fossils a short distance above it.

Section of Ermont formation in vicinity of Ermont mine

Massive bluish-gray limestone with black chert beds

	Feet
Poor exposures but probably bluish-gray limestone. Devonian fossils from dense bluish-gray limestone bed at base	230
Poor outcrop. Probably gray shale	100
Dense light-gray massive limestone. Effervesces readily with dilute acid	30
Sill of dark-green andesite porphyry	80
Dark-colored magnesian limestone with buff-colored patches which may be due to alteration	248
Black shaly limestone beds similar to basal beds	80
Sill of dark-green andesite porphyry	228
Black shaly magnesian limestone with sugary appearance. Beds mostly less than 6 inches thick. Bed 2 feet thick with twiglike bodies 10 feet from base	490
	1,486

Tilden formation.

The Ermont beds strike about N. 20° E., and have a fairly constant dip of from 20° to 25° southwest near the Ermont mine. A few hundred feet eastward from the top of the section, however, there is considerable minor folding.

CARBONIFEROUS SYSTEM

MISSISSIPPIAN SERIES

Mississippian rocks are the most widespread of the consolidated formations in the Argenta area. Fossils indicate the presence of both Madison and Brazer beds, but these have not been differentiated. The Madison formation is made up largely of massive bluish-gray limestone but black chert becomes abundant toward the top of the formation. Fossils were found throughout but are most abundant in the upper horizons. The most common organic remains are white cylindrical crinoid stems. Some beds appear to be made up almost entirely of them. Cup corals are the next in abundance. They are shaped like a cornucopia and in cross section the vertical partitions resemble somewhat the spokes of a wheel. Other fossils occur in less abundance. The Brazer formation does not differ

greatly in appearance from the Madison beds. It likewise includes numerous fossils and, like the Madison, contains beds made up almost entirely of crinoid stems.

No outcrop in the Argenta vicinity is suitable for the measurement of a section across the Mississippian beds, principally because of the faulting and folding. Faulting has caused an apparent thickening, particularly in the westerly part of the area. About 1,300 feet of Madison beds are exposed in the Melrose region[65] and about 1,200 feet were measured in the Bannack district.

PENNSYLVANIAN SERIES

The Pennsylvanian series embraces two distinct rock types in the Argenta district, a lower limestone formation and the quartzite and sandstone which overlie it. The lower Pennsylvania beds (Wells) resemble the Upper Mississippian (Brazer) beds in lithologic appearance and were not mapped as separate units. Fossil collections, however, indicate that both formations are present. Wells fossils were collected about 300 feet stratigraphically beneath the quartzite beds.

The Quadrant quartzite, which overlies the Wells formation, is exposed in several places within the map limits. The largest outcrops are in secs. 15 and 34 and a smaller remnant occupies a synclinal trough in sec. 20. Several other small patches have been mapped. Quadrant quartzite crops out continuously from the northern end of the Bannack district into the Argenta area and is everywhere similar in character. The lower beds are composed largely of white and pink vitreous quartzite which changes to sandstone toward the top of the formation. The upper part of the formation has been removed by erosion but the remaining beds are over 500 feet in thickness.

TERTIARY GRAVELS

The older gravel deposits of the Argenta district have been designated as "Upper Bench Gravels" and "Lower Bench Gravels" because of their relative positions. The "Upper Bench Gravels" reach an elevation of 6,800 feet. The lower terrace has been cut into the upper gravels and is best represented by the flat upon which the town of Argenta is built. Still more recently, Rattlesnake Creek has cut a deep channel into the lower bench and is now actively engaged in the process of degradation.

The formations underlying the terraces are not well exposed,

65. Richards, R. W. and Pardee, J. T.: op. cit.

although Rattlesnake Creek has cut through beds of sandstone and gravel east of Argenta. The surface of the terraces is nearly everywhere covered by a mantle of coarse, unconsolidated gravel. This loose material may have come from the weathering of the underlying beds or it may have been deposited by more recent streams. The superficial material is composed largely of rounded quartzite pebbles and boulders ranging from less than an inch to over a foot in size. They are mixed with some sand and black chert. The quartzite pebbles are predominantly pink or white and many show bedding plainly. Fossil remains found by Douglas[66] in beds similar to the terrace deposits indicate an Oligocene age.

QUATERNARY DEPOSITS

The Quaternary deposits are represented by recent stream gravels and glacial moraines. Rattlesnake Creek is depositing gravels in its present channel and, part of the superficial gravel covering the terraces may have been deposits by recent streams.

GLACIAL MORAINE

A well-developed glacial moraine has been deposited by a valley glacier at the mouth of the narrow canyon of Rattlesnake Creek in sec. 15 (Pl. XII, 1). Erosion has also left a small remnant of a moraine on a bench in the SE.¼ of sec. 15. These moraines represent the lower limits of the mountain glaciers that have moved down the present canyons. The boulders in the moraines consist mainly of granite or quartz monzonite with lesser amounts of quartzite and limestone. A moraine has been utilized to form a reservoir about a half-mile north of the map limits where Rattlesnake Creek cuts a narrow canyon through a glacial deposit.

INTRUSIVE IGNEOUS ROCKS

GENERAL FEATURES

The intrusive rocks of the Argenta district include quartz monzonite, granodiorite, andesite porphyry and dacite porphyry. The former two have been intruded into older rocks as large irregular bodies whereas the latter two occur as sills and dikes. The quartz monzonite and granodiorite rocks, like the intrusive rocks of the Bannack district, are, no doubt, genetically related to the "Boulder batholith"[67] and probably represent the high points or cupolas of a much larger body which erosion has not yet exposed to view. The most recent work indicates that the Boulder batholith

66. Douglas, Earl: Carnegie Mus. Annals, vol. 4, pp. 278-281, 1908.
67. Billingsley, Paul: Trans. A. I. M. E., vol. 51, pp. 31-56.

is of late Cretaceous or early Eocene age.[68] The andesite porphyry dikes cut the larger intrusive masses so that they were evidently intruded at least after the outer portions of the latter had cooled.

QUARTZ MONZONITE

Two exposures of quartz monzonite occur in the Argenta region. One mass crops out west of the town of Argenta and another is exposed near the southeast corner of sec. 17. Both outcrops resemble each other closely in lithologic appearance.

PETROGRAPHY

The rock is gray and medium to coarse-grained, but the light-colored minerals predominate over the dark ones. Quartz is clearly discernible in the hand specimens. The microscope shows the rock to be made up largely of light-colored minerals with biotite, hornblende and magnetite constituting the bulk of the dark minerals. The plagioclase crystals are lath-shaped and vary from 0.2 to over 2 millimeters in length and average about 0.5 by 1.0 millimeters in cross sections. They show very little alteration. Extinction angles show the plagioclase to be andesine (Ab_6-An_4) in composition. It constitutes about 45 per cent of the rock. Orthoclase is present in smaller amounts, estimated at 30 per cent. It occurs as tabular crystals or irregular masses and is characteristically zoned. Some of it is partly altered to sericite. Quartz is present as interstitial material and makes up about 15 per cent of the rock. The ratio of biotite to hornblende varies from place to place. In the sections studied the biotite was estimated at 7 per cent and the hornblende at about 3 per cent. The biotite commonly contains feldspars as poikolitic inclusions. Magnetite, titanite and zircon occur as accessory minerals. Magnetite comprises about 1 per cent of the rock, and apatite and zircon together constitute a still smaller amount.

GRANODIORITE

Two outcrops of granodiorite are exposed near the Dexter mine in sec. 17. They are separated by a narrow belt of altered limestone and are, no doubt, a continuous body beneath it. The exposures aggregate about a quarter of a square mile. No direct relationship was found between the granodiorite and the quartz monzonite. It seems probable, however, that they have had a common origin and that the latter represents a stage of deeper erosion. Some assimilation near the top of the cupolas may account for the lower silica content in the granodiorite.

68. Knopf, Adolph: U. S. Geol. Sur. Bull. 527, p. 34, 1913.
Stone, R. W. and Calvert, W. R.: Ec. Geol., vol. 5, pp. 551-557, 662-669, 744-764, 1910.

PETROGRAPHY

The granodiorite is a medium to fine-grained rock in which the light and dark minerals appear to be in about equal proportions. No quartz can be observed in the hand specimens. Thin sections show the rock to be composed principally of plagioclase, orthoclase and hornblende with little or no biotite. The boundaries of the mineral grains tend to coalesce, especially in the dark finer-grained phases. This same characteristic is marked in the quartz monzonite near the contacts with limestone. The lath-shaped plagioclase crystals have an average cross section of 0.5 by 0.2 millimeters and a maximum extinction angle of about 25 degrees which would classify it as andesine (Ab_6-An_4). The plagioclase is decidedly zoned and shows considerable alteration, particularly along fractures. Andesine constitutes about 50 per cent of the rock. Orthoclase is present as interstitial material and as rounded grains, some of which are over 2 millimeters across. The larger orthoclase crystals show zoning but it is not as marked as in the quartz monzonite. The amount present is estimated at 20 per cent. Green hornblende makes up about 25 per cent of the rock. It is variable in size and shape but averages about 1.3 by 0.4 millimeters in cross section. Basal sections show very perfect amphibole cleavage (Pl. XIII, 2). The hornblende commonly includes grains of magnetite and feldspar and some of it is partly altered to chlorite and limonite. In general, however, the hornblende is fairly free from alteration. Quartz makes up less than 5 per cent of the rock and occurs as interstitial grains. Magnetite constitutes about 3 per cent and titanite and zircon less than 1 per cent of the rock.

ANDESITE PORPHYRY

The andesite porphyry intrusions in the Argenta district occur chiefly as sills although some andesite porphyry was found to occur as dikes. The largest outcrops of andesite porphyry are exposed near the Ermont mine, in secs. 26 and 35. The Ermont intrusives have the general characteristics of sills and in places they clearly cut across the bedding planes of the limestone. It is possible that the sills north of Rattlesnake Creek, in sec. 24, are the northward extensions of the intrusives near the Ermont mine. They are similar in appearance although, in general, the Rattlesnake sills are more intensely altered. A. H. French found andesite porphyry in a tunnel on the Tuscarora property. Thin sections show some of the dikes across the creek from Argenta in sec. 29, to be andesite por-

phyry, although most of these dikes usually contain considerable quartz.

PETROGRAPHY

Two types of andesite porphyry prevail in the Argenta region. One type is a dense grayish-green rock that does not show marked porphyrytic characteristics in hand specimens and the other is a grayish-green rock with very evident lath-shaped phenocrysts of black augite in a dense groundmass. No doubt, both have come from a common source.

The microscope shows the former to be comprised of a microcrystalline groundmass with phenocrysts of altered plagioclase and orthoclase and alteration remnants of ferromagnesian mineral (Pl. XIII, 3). Magnetite grains are disseminated throughout the entire rock. Extinction angles indicate that the plagioclase has the composition of andesine. Most of it is wholly or partly altered to calcite and sericite and the orthoclase largely to sericite. Only the alteration remnants of the ferromagnesian minerals remain. They consist chiefly of chlorite, talc, and limonite. Patches of calcite occur throughout the rock. Quite a little secondary silica is present in the groundmass. Little primary quartz was noted. Although alteration makes the classification of the rock uncertain, evidence indicates that it is an andesite porphyry.

The andesite porphyry with the abundant augite phenocrysts is not so highly altered as the dense rock. Feldspar and augite phenocrysts occur in a microcrystalline groundmass composed largely of small lath-shaped feldspars and constitute about one-third of the rock. The plagioclase phenocrysts range in length from about 0.5 to 1.0 millimeters and the average augite crystal is about 1.0 millimeters long by 0.3 millimeters wide. Occasional augite phenocrysts are over 1 centimeter in length. The plagioclase feldspars have the composition of andesine and are considerably altered but many still retain the twinning striae. Orthoclase phenocrysts are less abundant than andesine. The augite is light-green in ordinary light and most of the crystals are twinned. Calcite occurs along fractures but, in general, the augite is only slightly altered. It commonly includes magnetite and irregular patches of groundmass material. Augite constitutes about 50 per cent of the phenocrysts. Magnetite constitutes about 2 per cent of the rock. Little or no quartz was noted in the thin sections. This rock is classified as an augite-andesite porphyry.

DACITE PORPHYRY

A number of dikes cut the quartz monzonite west of Argenta.

They are similar in appearance to andesite porphyry, some contain considerable quartz. They range in color from almost white to grayish-green, depending upon the degree of alteration. All contain some quartz but only those containing it in appreciable amounts are termed dacite porphyries. All are probably phases of the same intrusive.

PETROGRAPHY

The dacite porphyry is almost white to grayish-green in color and is noticeably porphyritic. Phenocrysts of bleached feldspar and glassy quartz are clearly visible in the hand specimens. Small patches of limonite give the rock a spotted appearance.

Thin sections show the rock to contain phenocrysts of feldspar, augite and quartz in a felted groundmass. The phenocrysts make up about one-third of the rock. Except for the presence of more quartz, the dacite porphyry does not differ greatly in appearance from the andesite porphyry. Both phenocrysts and groundmass are considerably altered but the twinning striae are still visible on the plagioclase crystals. All of the quartz phenocrysts observed were rounded in outline and most of them showed marked embayments (Pl. XIII, 4).

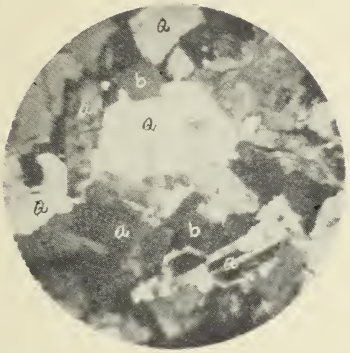
RHYOLITE PORPHYRY

A highly altered igneous rock occurs across the creek from Argenta. It is a white porous rock with numerous casts, some lined with limonite. The rock has a sugary appearance and is characterized by a high porosity. The square shape of the cavities and the fact that many are entirely free from limonite indicates that they may once have been occupied by pyrite. This rock is said to contain gold in small amounts. It is tentatively classified as an altered rhyolite porphyry because of the light color and the presence of quartz phenocrysts.

CONTACT METAMORPHIC EFFECTS

The most intense metamorphic effects have been observed in the limestone beds near their contact with granodiorite and quartz monzonite. Granodiorite has intruded shale beds near the Dexter mine but the contact effects are much less noticeable than in the limestones near by. The shales have been silicified and are rust-brown in color—apparently due in part to the weathering of included iron-bearing minerals.

The most common effects in the limestones are recrystallization and garnetization. Vesuvianite, epidote and tremolite were observed in association with the garnet but epidote is much less com-



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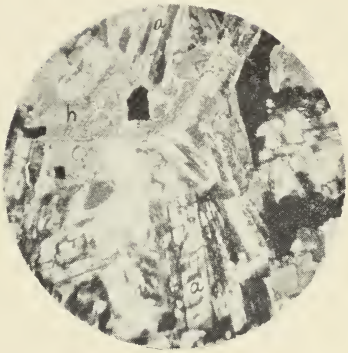

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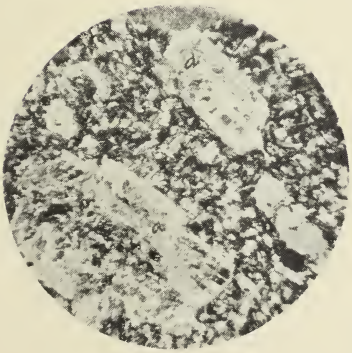

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PHOTOMICROGRAPHS OF INTRUSIVE ROCKS FROM THE ARGENTA DISTRICT

1. Quartz monzonite from N.E.¼ of sec. 20. Quartz (white), biotite (b), andesine (a). Polarized light. Magnification 23 times.
2. Diorite from N.W.¼ of sec. 17. Andesine (a), hornblende with well-developed amphibole cleavage (h), black mineral in center of hornblende is magnetite, irregular black patch is hornblende at extinction. Polarized light. Magnification 28 times.
3. Andesite porphyry from the larger intrusive body in N.E.¼ of sec. 35. Shows partly altered andesine crystals in silicified microcrystalline groundmass. Polarized light. Magnification 28 times.
4. Dacite porphyry dike from N.W.¼ of sec. 29. Shows microcrystalline groundmass and partly resorbed quartz crystal (white). Ordinary light. Magnification 14 times.

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mon than in the Bannack district. The most widespread contact metamorphic product is a dense greenish-yellow greasy-appearing rock. It is well-developed around the northern border of the quartz monzonite mass across the creek from Argenta. Thin sections show this rock to be composed largely of isotropic garnet. In addition to the garnet, the ore bodies around the contacts afford further evidence of introduced material.

The granodiorite and quartz monzonite also show a difference near the limestone contacts. They are darker-colored and noticeably finer-grained. Thin sections show a lower quartz content and a marked tendency to coalescence of the feldspar grains. Analyses of the intrusive rocks near the limestone contacts in the Bannack district show an increase in lime, magnesia and iron.[69]

The contact metamorphic effects of the andesite porphyry are much less intense than those of the granodiorite and quartz monzonite. Silicification of the limestone beds is the most evident result. The andesite porphyry itself is denser in appearance near the contact.

EXTRUSIVE IGNEOUS ROCKS

RHYOLITE PORPHYRY

A patch of dense light-gray porphyritic rock occurs near the southeast corner of sec. 36. It contains in a highly altered groundmass, many phenocrysts of angular quartz and numerous patches of calcite, which may be the decomposition product of feldspar. Because of the abundant quartz and light color this rock is classified as a rhyolite porphyry.

TRACHYTE PORPHYRY

A dense gray rock with well-developed phenocrysts of orthoclase occurs on top of the Quadrant quartzite in the southeast corner of sec. 34 and a similar appearing rock was found on the top of the ridge in the NE.¼ of sec. 22 and another outcrop on the high ridge near the center of sec. 14.

The microscope shows the rock to be composed of orthoclase phenocrysts, aggregating about 25 per cent of the rock, in a dense, partly silicified groundmass. Very little primary quartz was noted. The orthoclase phenocrysts are slightly altered to sericite.

69. Idem, p. 16.

DEFORMATION

GENERAL FEATURES

The structure of the Argenta region is complex and only the broader features are shown on the map and sections. The sedimentary beds have been compressed into a series of folds with a northerly trend. In places these folds have been broken and displaced along fault surfaces. Two distinct types of faults have been developed. East-west compressional forces have caused older rocks to be shoved over younger rocks along thrust faults, and later, other forces resulted in the further breaking of the formations by normal faults. The faults are made evident by the cutting out of beds, the severe folding and tilting that interrupt their continuity and in places by the direct observation of the fault surfaces.

The deformation in the Argenta district is merely the local expression of a great system of folding and overthrust faulting which is known to extend from Canada into Utah. It has been described in the Philipsburg district by Calkins,[70] by Richards and Pardee[71] in the Melrose district, by Richards and Mansfield[72] in Idaho, and by Willis[73] in northern Montana, and in the Bannack area elsewhere in this report.

PRINCIPAL FOLDS AND FAULTS

The most prominent structural feature is the broad anticlinal fold which occupies much of the Argenta area and extends to the north beyond the limits of the map. It is around this fold that the best records of the sedimentary rocks are available. The fold is not intact but has been broken by faults. A smaller anticlinal fold separates two small synclines in the eastern part of the district. North of Argenta the eastern syncline is occupied by Quadrant quartzite which erosion has not entirely removed. Another less conspicuous fold is developed near the western border of the mapped area. Minor folds are abundant. Intense minor folding can be observed from the road just northeast of the southwest corner of sec. 19.

Thrust faults account for much of the deformation. One has shoved Madison beds over Quadrant quartzite in the western part of the area and another fault of less displacement has moved Spokane beds into contact with Tilden limestone in the vicinity of

70. Emmons, W. H. and Calkins, F. C.: U. S. Geol. Sur. Prof. Paper 78, 1913.
71. Richards, R. W. and Pardee, J. T.: U. S. Geol. Sur. Bull. 780, 1925.
72. Richards, R. W. and Mansfield, G. R.: U. S. Geol. Sur. Bull. 577, 1914.
73. Willis, Bailey: Geol. Soc. of America, Bull. vol. 13, pp. 305-52, 1902.

the Midnight mine. A major normal fault trending north and south with several splits has dropped upper Madison beds into contact with Ermont limestones in the western part of the area. Numerous small normal faults were noted in many places but because of the scale these are not shown on the areal map.

Folding evidently took place before intrusion of the igneous rocks in the Argenta district because they can be observed cutting across the folds. As the late Tertiary lavas have been folded and faulted also, it is evident that there were at least two periods of deformation or else the process was continuous. The most intense folding probably occurred in the Cretaceous period. Billingsley[74] has placed the beginning of the deformation in western Montana in the late Cretaceous.

ORE DEPOSITS

HISTORICAL SKETCH OF MINING

After most of the available claims had been staked in the Bannack district numerous prospectors spread over the nearby hills in search of new "diggings". Some placer ground was discovered near Argenta but it was not until the spring of 1865 that A. M. Esler of Bannack discovered the Legal Tender, the first important mine in the Argenta district.[75] The ore was rich but as the shipment charges to Swansea, Wales, the nearest smelter, consumed most of the profit, Mr. Esler decided that same year to build a smelter, the first in the State of Montana. It had a capacity of six tons per day.[76] Subsequently a refining furnace or cupel was added because the freight charges prohibited the shipment of the lead. Mr. Esler sold his smelter to S. H. Bohm and Company of Helena, Montana, who operated it as a custom plant. They also acquired the Ferdinand and Brownell mines. A second smelter was built in 1866 by Tootle Leach & Co. of St. Louis, for the treatment of the Tuscarora ore. This smelter was purchased by W. A. Clark, in 1869. The third smelter was built in 1867 by the St. Louis & Montana Mining Co., principally for the treatment of the Iron Mountain ore. It was afterward owned and operated by E. S. Ball, who in turn sold to the P. J. Kelly Placer, Quartz & Reduction & Smelting Co. A fourth furnace, constructed of inferior fire-brick, melted upon the first heating.

For a number of years the various smelters continued to treat

74. Billingsley, Paul: Trans. A. I. M. E., vol. 51, pp. 31-56, 1915.
75. French, G. W.: Mining Truth, Spokane, Wash., p. 23, April 3, 1930.
76. Browne, J. Ross, Mineral Resources of the United States for 1866. Montana, pp. 310, 1868.

ore mainly from Argenta, though some ores from the Blue Wing and other district were treated also. In later years the ores have been hauled to the railroad at Dillon and shipped to various smelters and mills in Montana and Utah.

Like those in the Bannack district, the mines at Argenta have been worked at intervals in recent years. In 1928 the Ferdinand, Iron Mountain and Brownell shipped considerable ore, although little activity was evident during the summer of 1929. In general, the activity follows the trend of the metal market.

Lead and silver are the most important metals produced in the Argenta district. The gold production is next in importance and considerable copper and zinc have been mined. Of 30 or more mines and prospects in the district, 15 account for nearly all the production. Seven account for most of the lead and silver produced, four for most of the gold, two for much of the copper and one for most of the zinc.

Practically all the production has come from the lode mines. Some placers were worked but no figures are available as to the amount of gold produced. Many of the lode mines were operated before statistics were recorded so that the production figures for a number of them are merely estimates based largely upon the size of the underground excavations and the grade of the ore. Messrs. A. H. and George French, who are familiar with the history of most of the mines, have contributed much information. The total production of the Argenta district is estimated at $1,500,000.

CLASSIFICATION OF THE ORE DEPOSITS

Ore deposits are commonly classified for descriptive purposes according to their metal content; according to the enclosing wall rock; according to their genesis; or according to the forms of the ore bodies. A combination of the latter three is used in the following description and comparison of the deposits:

1. Pipe-like ore bodies in limestone:
   Tuscarora
   Gov. Tilden
   Florida
2. Tabular ore shoots along bedding planes in limestone:
   Legal Tender
   Spanish mine
   Fraction (in part)
   Wooley " "
   Coolidge " "
3. Tabular ore shoots along fissures in limestone:
   Brownell
   Mauldin
   Anaconda

Coolidge (in part)
Goldsmith " "
Fraction " "
Wooley " "

4. Contact deposits in limestone:
   Iron Mountain
   Argenta Mining Company
   Ermont
5. Deposits along fissures or shear zones in quartzite:
   Carbonate
   Ground-hog
   Goldfinch (in part)
   Lookout
6. Deposits along fissures in shale:
   Golden Era
   Rena
   Midnight
   Goldfinch (in part)
   Dexter
   Gladstone
7. Ore shoots along veins and shear zones in quartz monzonite:
   Ferdinand
   Jack Rabbit
   Copper Bell
   Bella

PIPE-LIKE ORE BODIES IN LIMESTONE

Pipe-like ore bodies in limestone have been the source of much of the lead and silver produced in the Argenta district. The deposits of this type usually consist of pipe-like shoots which commonly split and rejoin as they are followed along the dip of the limestone beds. The mineral-bearing solutions, no doubt, followed lines or zones of weakness, but control fissures are usually not obvious. The shoots are usually continuous except where they are interrupted by faults. Prescott[77] has clearly described the underlying principles of deposits of this type in Mexico. In prospecting this type of deposit the ore should be followed as closely as possible for even with a thorough knowledge of the stratigraphy and the principles involved it is extremely hazardous to run long exploration tunnels for the intersection of the ore shoots.

TUSCARORA MINING AND SMELTING CO. PROPERTY

The Tuscarora Mining and Smelting Co., property includes two of the most important mines in the Argenta district. The group embraces the Tuscarora, Gov. Tilden, Florida, Wooley, Fraction, Fraction Placer, Reform, Burleigh, and Spring claims, all in sec. 18. Most of the work and production has been confined to the first two. The B. F. White estate of Dillon, Montana, owns one-half interest

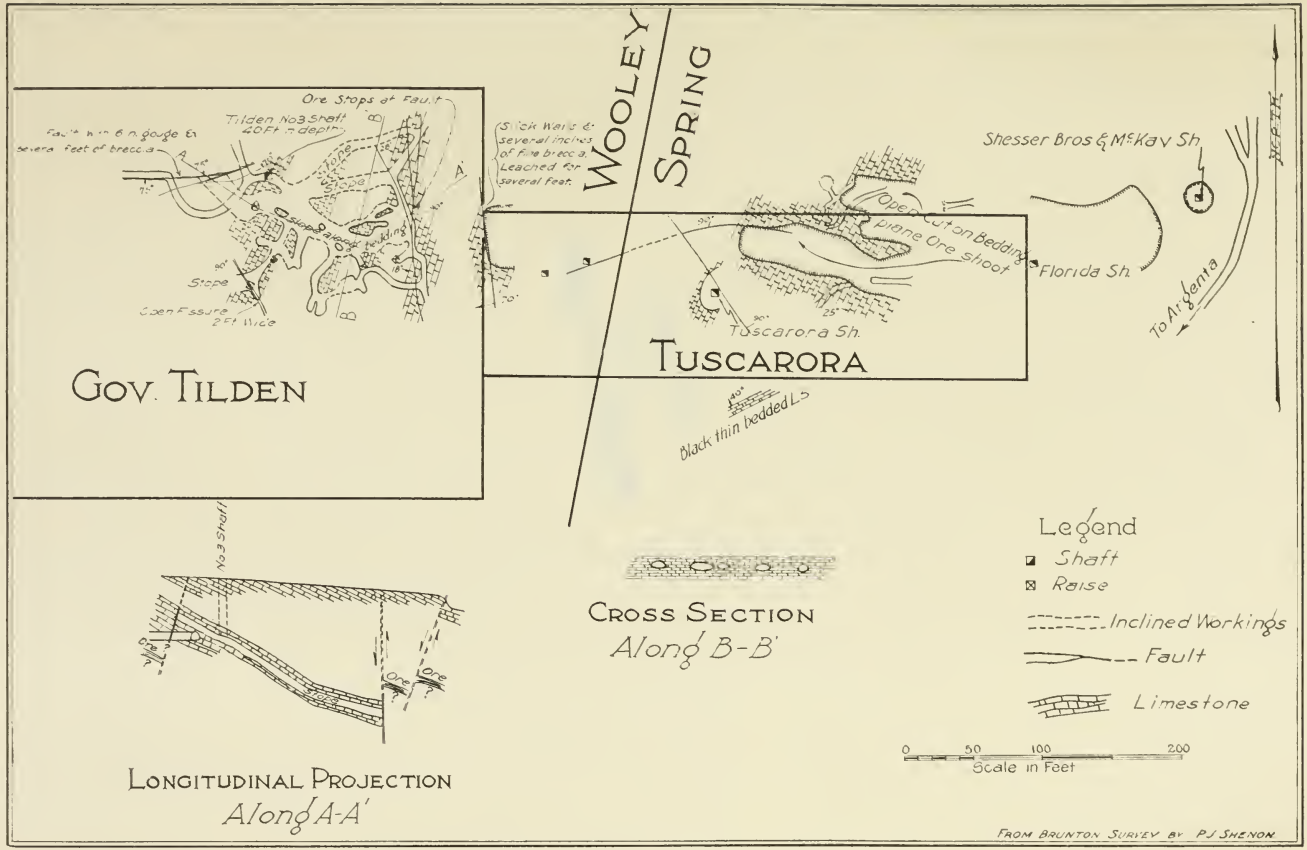
77. Prescott, Basil: Eng. and Min. Jour. vol. 122, pp. 246-253, 289-296, 1926.

and the Anaconda Copper Mining Co., one-half interest in the Gov. Tilden, Florida, Wooley, Fraction, Fraction Placer, Reform, Burleigh, and Spring claims. The Anaconda Copper Mining Co., has the entire ownership in the Tuscarora.

The Tuscarora was discovered in 1865, by Amede Bessette and Wash Stapleton. The Gov. Tilden was discovered a short time later. W. G. Gallagher and LaFayette Scott acquired the mine from the locators and extracted considerable ore in the late 'seventies. W. A. Clark bought LaFayette Scott's interest in the early 'eighties and continued to run the smelter partly with ore from the Tuscarora and partly with custom ores. During this time the incline was run from the Tuscarora into the Florida, where a fault is said to have terminated the ore. Clark shipped several cars of ore from the Tuscarora and the Gov. Tilden in 1895-96, following which Gallagher made several shipments. Frank Benton leased the property in 1898-99, and shipped 195 tons of ore from a pipe-like shoot in the Gov. Tilden which ran south and west along the bedding and then turned and crossed over the incline. None of his workings are now open. During the period from 1914-21, Messrs. A. H. French and W. G. Graeter shipped ore and some concentrates from the Gov. Tilden, which had a gross value of $30,000. The concentrates were made by jigging the dumps. With the exception of two cars washed by McKay and Ross these are the only concentrates that are known to have been shipped from the property. The size of the excavations indicate that the Tuscarora and Florida produced from 5,000 to 7,000 tons of ore and the Gov. Tilden from 2,000 to 3,000 tons. These figures are in accordance with estimates made by A. H. French.[78]

Most of the ore from the Tuscarora claim was extracted from open cuts although considerable ore is said to have been taken out of the incline extending from the Florida shaft which ran directly beneath the open cuts. This incline, which is no longer accessible, connected with the Tuscarora shaft to the west and with the Shesser Bros. and McKay shaft to the east. Old maps from the files of W. A. Clark show several stopes just north of the Florida shaft. This shaft was 80 feet deep, the Shesser Bros. and McKay shaft 130 feet, and the Tuscarora shaft about 120 feet deep. All of the ore from the Gov. Tilden claim was mined by underground methods. About 300 feet of inclined workings were opened on ore and, in addition, about 600 feet of exploration drifts were driven.

78. Personal communication.



MAP OF THE TUSCARORA AND GOV. TILDEN MINES

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The ore deposits at the Tuscarora and Gov. Tilden mines are in the gray crystalline Tilden limestone just beneath the contact with the black thin-bedded Ermont limestone. The limestone beds strike, in general, N. 20° E., and have an average dip of about 25° SE. The principal ore shoots were pipe-like in cross section and followed the bedding planes of the limestone. The inclined working beneath the open cuts indicates that there are at least two productive horizons. The shoots, although commonly splitting around blocks of limestone, have a definite east-west trend. This trend may be controlled by fissures, but, if so, they are not clearly defined. The ore is displaced by a series of normal faults, striking north and northeast. These faults have steep dips which vary from 70° to 90° and are characterized by well-defined walls, usually several inches of gouge and, in some cases, by several feet of brecciation. The Gov. Tilden ore shoot is terminated on its eastward extension by one of these faults which strikes north and dips about 90°. The black limestone bed with the twig-like bodies serves as an excellent horizon marker for structural correlation.

The ore was almost entirely oxidized, although residual patches of galena still remain along the walls of the deposits. A. H. French[79] describes the ore from the Tuscarora as a "sand carbonate" which he says was reported to assay as high as 60 per cent lead and 60 ounces silver. The average metal content was probably considerably lower. The ore was shipped directly to the smelter without concentration and with very little sorting. Ore shipped from the Gov. Tilden in 1898-99 gave gross smelter returns of $27.60 per ton. The average quotations for lead and silver for those years were $4.12 and 59c, respectively. Assays indicate that the ore carried $3 to $5 per ton in gold and that the ratio of silver was less than one ounce to the unit or per cent of lead. On the basis of this ratio, these shipments must have averaged about 20% lead. This figure is in accordance with the metal content of the ore shipped from the Gov. Tilden by Messrs. A. H. French and W. G. Graeter at a later date.

Practically no commercial ore is exposed in either the Tuscarora or Gov. Tilden at the present time. Some low-grade jasperoid wall-rock remains but it has no commercial value at present. A careful study of the normal faulting should lead to the discovery of segments of the faulted ore bodies. Although the ore shoots occasionally split around limestone blocks, there is little doubt that

79. Personal communication.

they were continuous on the dip of the limestone beds, except where displaced by faults.

No exact measurements were secured on the throw of the faults so that the position of the ore indicated as probable in the longitudinal projection through the Gov. Tilden ore body is arbitrarily placed (Pl. XIV). Any work contemplated in these properties should be carefully planned and all available sources of information should be consulted in order to determine the position and extent of the older workings.

The Wooley claim overlaps parts of the Gov. Tilden and Tuscarora claims. Practically all of the work on the Wooley has been confined to a 30-foot inclined shaft and an open cut along a fissure striking N. 10° W., and dipping about 90°. Most of the ore occurred along the fissure although some mineralization is evident along the bedding planes. The production from the Wooley has been small.

The Florida claim is situated south of the Gov. Tilden and overlaps much of the Tuscarora. It is 1,500 feet long by 550 feet in width and was located with the long direction almost at right angles with the Tuscarora. Most of the work has been confined to the Shesser Bros. and McKay shaft, the Florida shaft, and the incline mentioned above. Some pits, a shallow inclined shaft and a short tunnel have been opened near the southern boundary of the claim. The production, which could not have been large, came mostly from the incline south of the Tuscarora.

The Fraction is situated south of the Florida and Wooley and overlaps portions of each. Practically all of the work has been confined to the extreme southwest corner of the claim where two shafts, one inclined, and several cuts have been opened. Drifts have been run from the bottom of the shaft. Small stopes indicate that the property has produced some ore. The ore apparently was along bedding planes in limestone and also along a well-defined fissure cutting across the limestone beds. The ore resembles that from the Tilden and probably had about the same metal content.

Little or no work has been done on the Fraction Placer, Burleigh, Reform or Spring claims. The buildings are located on the last-named claim.

TABULAR ORE SHOOTS ALONG BEDDING PLANE IN LIMESTONE

Only one important property in the Argenta district, the Legal Tender, has produced ore solely from tabular ore shoots along bedding planes in limestone. The mineral-bearing solution may have followed fissures in its course upward, but development work has

thus far shown the ore in the Legal Tender to occur only along the bedding planes. The ore follows one horizon but is not continuous along it for it pinches out laterally and is displaced by faults. In prospecting ore deposits of this type, unless there are good reasons to suspect that other bedding planes are mineralized, it is advisable to follow the horizon of known production.

LEGAL TENDER MINE

The Legal Tender mine, which is located in the SE.¼ of sec. 24, was discovered in 1865 by A. M. Esler of Bannack. It was one of the first silver-lead mines discovered in Montana and had the distinction of supplying ore for the first smelter built in the state.[80] The ore was at first shipped to Omaha by ox-teams, from there by train to New York and thence across the Atlantic to Swansea, Wales. George M. Brown bought the property from Mr. Esler and leased to Cornelius Bray, who mined ore worth $10,000 from a small pocket. Bray also shipped some ore from the Colin McDonald property, just south of the Legal Tender. George Dart of Dillon and J. A. Brown of Melrose later acquired an interest in the property. It is now owned by James Eddy, a nephew of George M. Brown, and the J. A. Brown estate. The production of the Legal Tender is estimated at $150,000.[81]

The ore occurs along the bedding in Tilden limestone not far beneath the contact with the Ermont formation. The beds in the vicinity of the mine strike N. 15° E., and dip 45° S. Most of the ore was mined through an inclined shaft over 100 feet in depth which is now only partly accessible. The stopes average about four feet in width, but the fresh appearance of the walls suggests that the ore body may have been narrower. The ore was a soft "sand carbonate" which ran about 300 ounces in silver per ton. A few residual patches of galena remain along the walls near the termination of the ore shoots.

SPANISH MINE

A small ore shoot was mined on the Spanish claim about 500 feet north of the Legal Tender ore body. The workings consist of a shallow shaft and some small stopes. The property is owned by the Anaconda Copper Mining Company. The ore occurs along a bedding plane in Tilden limestone which here strikes N. 30° E., and dips 48° S. The ore appears to be along the same bed as the Legal Tender ore shoot, but it has been offset 50 feet to the west

80. French, George W.: Mining Truth, Spokane, Wash., April 3, 1930, p. 23.
81. French, A. H., personal communication.

by steeply-dipping faults which strike N. 60° W. The production of the Spanish Lode has been small.

TABULAR ORE SHOOTS ALONG FISSURES IN LIMESTONE

Tabular ore shoots along fissures in limestone have accounted for a considerable part of the production in the Argenta region and therefore warrant consideration. The ore bodies are found along steeply dipping fissures and are usually not far distant from igneous rocks. The fissures are well-defined and can be easily traced. The mineral-bearing solution of course, followed the fissures. Cross fractures are common but most of them appear to bear no relation to the ore deposition. The junction of two splits in the Anaconda vein tended to localize the ore and it is probable that pre-mineral cross-fractures were also effective. To that end, no important cross-fractures were noted in the short time spent in the examination of these mines but a more thorough examination of these mines would probably reveal them. The most significant structural feature noted, and one that might assist in the search for ore, is the "slickensided" fissures and slump fractures developed in the vicinity of the ore bodies. It seems quite clear that slumping is an important post-mineral process which should be a significant aid to prospecting along the fissures.

BROWNELL MINE

The Brownell claim is long and narrow and lies partly in sec. 19 and partly in sec. 30. It was located in 1865 by Harry Griffiths, and was the second mine discovered in the Argenta district. Considerable ore was shipped to the St. Louis & Montana smelter in the late 'sixties and early 'seventies by E. S. Ball and others. S. H. Bohm & Co., of Helena bought the Brownell in 1871, and shipped ore to their smelter. A. J. Shoemacher shipped 1,000 tons of ore to the St. Louis & Montana smelter during the years 1882-85. The property lay idle until 1890, when lessees took out ore worth several thousand dollars. J. E. Oppenheimer of Butte, Montana, bought the property a short time later and it is still owned by the Oppenheimer estate. James and George Knapp shipped 20 cars from the west vein in 1922 and George D. Spafford has since shipped eight cars from the same vein. The production is estimated at 5,000 tons.

The Brownell ore bodies were worked through a shaft which was sunk to a depth of 150 feet, but which is now open only for 110 feet. Part of the old workings are no longer accessible. The principal working, the 80-foot level, is open for but 50 feet south of the shaft. The ore occurs in shoots in limestone along a well-

defined fissure which strikes north and dips 80° W. The vein splits on its downward course into the east and west ("Knapp stope") veins. A short shoot about 15 feet wide was mined at the junction of the splits on the 80-foot level. Stopes with an average width of three feet and a south rake extend to the surface on the north side of the shaft. The "Knapp stope" pinched and swelled but averaged about two feet in width. The hanging wall is slickensided and highly altered, whereas the foot-wall is usually a hard crystalline limestone with numerous vugs. The "slickensided" walls have irregular rolling surfaces and in places show copper carbonate.

The ore was almost entirely oxidized and was predominantly a "sandy" lead carbonate. Hard jasperoid ore is found near the walls. The ore shipped from the Knapp stopes averaged 28 per cent lead, and shipments by Mr. Spafford averaged 31 per cent lead, 6 ounces per ton in silver, 0.8 per cent copper and 90 cents per ton in gold.[81] A small car of ore from the top of the large stope on the 80-foot level contained 11 per cent copper.

MAULDIN MINE

The Mauldin property includes two claims, the Rittenhouse and the Louis Philip, which are located in the NW.¼ sec. 29. James Mauldin located the property and did considerable prospecting. He and E. S. Ball had an early-day lawsuit over ownership which was decided in favor of Mauldin. The Mauldin estate has recently sold the property to Frank Wilson. Four shafts and a long tunnel are the principal openings, but only part of them are now accessible. The deepest shaft was sunk in limestone to intersect the quartz monzonite contact, but was abandoned because of the heavy flow of water. No ore was encountered. Another shaft was sunk to a depth of 30 feet on a 50° incline and then 20 feet vertically. Ore was encountered near the bottom and about 150 tons were mined. The Eaton shaft, which was named after Professor Eaton, who was probably the first mining geologist in the district, encountered an ore body at a depth of 100 feet. The shaft was sunk on a fissure striking N. 10° W., which dipped 80° W. The wall rock next to the ore body is strongly "slickensided" and brecciated material resembling an old filling occupies fractures near the top of the stope. The slickensides and brecciated material are believed to have formed from slumping due to the shrinkage which resulted from the removal of material during oxidation of the sulphide ore. Smith Ball mined the ore and shipped it to the Stapleton smelter. No

81. Spafford, George D., personal communication.

figures are available as to the production from this ore body, the old stope is partly filled and none of the old smelter records are available. Soft lead carbonate was the principal ore mineral. The silver content was about 3 ounces per ton and the ore carried about $1.00 to the ton in gold. The ore resembles that of the Brownell and probably had a similar metal content, although the average copper content is said to have been higher.

ANACONDA MINE

E. S. Ball located the Anaconda property after he had lost his lawsuit with James Mauldin. He sank a 30-foot shaft and encountered an ore body, and later he sank a working shaft 60 feet deep. The ore was treated at the St. Louis & Montana smelter. Before the ore body was worked out the property was sold to the P. J. Kelly Placer, Quartz & Reduction & Smelting Company, who continued to ship ore to the smelter. This concern finally went into receivership. The property was later acquired by J. E. Oppenheimer of Butte, Montana.

The ore occurred as an irregular tabular body along the Mauldin fissure, a short distance north of the Mauldin incline. The ore was largely a soft lead carbonate with a low silver content. The property produced about 500 tons of ore.

COOLIDGE MINE

The Coolidge mine, formerly known as the St. Joseph, was located in the early 'seventies by Thomas E. Tuttle, and is situated in the SE.¼ of sec. 18. It was taken over by E. S. Ball who shipped considerable ore to the St. Louis & Montana smelter. The Golden Era Company then sank an inclined shaft to a depth of 170 feet, but made no shipments. Alfred Graeter shipped 200 tons of ore from the dumps in 1898. The property was later located by Messrs. George W. and A. H. French, who are the present owners.

The ore at the Coolidge mine is enclosed in the basal beds of the Ermont formation, and for the most part followed along a well-defined fissure. Near the surface the fissure parallels the bedding but steepens and leaves the bedding at a depth of 40 feet. A sill of andesite porphyry forms the hanging-wall of the ore to the point where the vein steepens. The ore shoot was about 10 feet high and from two to seven feet wide. It extended for about 100 feet beneath the surface and raked to the south at an angle of 35°. The stopes indicate a production of about 500 tons.

The ore is largely oxidized but contains residual patches of

galena. The average metal content is about 10 per cent lead, 20 ounces in silver, and $1.80 in gold per ton.

GOLDSMITH MINE

The Goldsmith mine is in the NE.¼ of sec. 30. It was located in the late 'eighties by Thomas Judge and Thomas Fox, who made no shipments. Mark Bray relocated the property and shipped a little ore, but soon sold a half interest to a Mr. Smeed. Mr. Bray's half interest was shortly afterward purchased by W. A. Clark, who mined most of the ore produced. J. E. Oppenheimer of Butte, Montana, bought the Smeed interest, which is still owned by the Oppenheimer estate. In the transfer of 1928, the Anaconda Copper Mining Company acquired the Clark interest. A. H. French[82] estimated the production of the Goldsmith at 300 tons, which is corroborated by the size of the stopes.

Access to the property is gained through three short tunnels and a shallow incline. One tunnel is 120 feet long, another 60 feet and a third 25 feet long. The second and third and the incline intersect the ore body, but the first has encountered only brown-stained marble. The ore was mined in underhand stopes which are now, for the most part, closed.

The ore, found along a well-defined fissure in a coarse-grained white marble, strikes N. 80° W., and dips 70° N. The ore is predominantly hard and siliceous and is irregular in width, although it is never wide. The principal minerals of commercial importance are chrysocolla, malachite, tenorite, cuprite, copper pitch, native copper and gold. Near the ore bodies the marble is stained a chocolate-brown color, a fact which should prove a helpful guide in prospecting for further ore, particularly as the outcrops are covered by gravel. According to Mr. French,[83] his shipments from the Goldsmith had a gross value of $75 per ton.

CONTACT DEPOSITS IN LIMESTONE

Two types of contact deposits in limestone are found in the Argenta district. Silver-lead deposits at the contact between quartz monzonite and Upper Mississippian limestones are represented by the Iron Mountain and the Argenta Mining Company's property, and gold deposits at the contact between andesite porphyry and limestone are represented by the Ermont mine. The Iron Mountain mine which belongs to the first group has been one of the important producers in the district. The Argenta Mining Company's property

82, 83. French, A. H. personal communication.

was not sufficiently developed, in 1929, to determine its worth. The Ermont mine is probably the newest mine in the Argenta district, and has a tonnage of low-grade gold ore partly tested. The work on the property is being directed toward proving a low-grade ore deposit large enough to justify a mill.

IRON MOUNTAIN MINE

The Iron Mountain mine was discovered in 1869, and was worked by the St. Louis & Montana Mining Co., and later by E. S. Ball, who purchased both the mine and smelter from the original company. Mr. Ball sold the property to P. J. Kelly Placer, Quartz & Reduction & Smelting Company, and it was finally acquired by Oppenheimer estate. No figures are available as to the production of the Iron Mountain mine, but the size of the stopes indicates that considerable ore was produced. Much of the ore was shipped to the local smelters in the early days. The mine is located in the NE.¼ of sec. 30.

Two tunnels and two inclined shafts are the principal openings into the Iron Mountain mine. The longer incline started in quartz monzonite, intersected the limestone at 100 feet and continued down the contact another 200 feet. Near the bottom the shaft becomes very flat. The upper part of the incline is no longer accessible but the stopes can be entered through the lower tunnel. The lower tunnel starts near the level of Rattlesnake Creek and runs northward about 700 feet to connect with the longer inclined shaft. A considerable head of water, most of which comes from near the contact, flows from this tunnel. Another incline, called the No. 1, is caved near the surface but access can be gained to the old stopes through the Knapp tunnel, which is about 250 feet long.

The ore in the Iron Mountain mine is found in limestone at the contact with quartz monzonite. The contact is usually sharply marked by a band of white altered material from six inches to a foot wide. The ore shoots, where observed, were more or less tabular bodies paralleling the contact but varying considerably in size both vertically and horizontally. The stopes on the 100-foot level of the main incline have a maximum width of about 20 feet. These stopes are said to have reached the surface. Steeply-dipping fractures appear to have localized the ore in the vicinity of the Knapp stope. The No. 1 incline intersects the same fissure that cuts the most productive part of the Knapp ore body. The enrichment along the north-south fissures may not have been primary.

The ore is almost entirely oxidized although residual patches

of galena and unaltered pyrite cubes are scattered through the ore on the lower levels. The richer ore is massive brown cerussite and limonite with patches of dark-gray anglesite and irregular green disseminations of malachite. Malachite stains are found throughout the ore and usually a band of it is found along the hanging wall of the deposits. Dark gray anglesite of a greasy luster is the predominating ore mineral among the specimens collected from the lower level. Native copper is found in the lower stopes and was observed in lumps as large as 6 inches across. It is mixed with cuprite and malachite. The average metal content[83] of the ore shipped from the Knapp stope was 18 per cent lead, 12 oz. silver, and $3.00 in gold per ton. Three cars shipped from the lower workings had a similar metal content.

The contact in the vicinity of the Iron Mountain mine rarely carries commercial ore. Nevertheless the contact merits careful prospecting. The heavy flow of water at the contact should be seriously considered before attempting work below the level of the lower tunnel.

ERMONT MINE

The Ermont mine property includes 31 claims which lie, for the most part, in sec. 30, T. 6 S., R. 11 W. The claims were located in 1926 by D. V. Erwin and W. J. Corbett, who prospected the ground until 1927, when the property was bonded to the Standard Silver & Lead Company of Spokane, Washington. This company dug several trenches and sank several shallow shafts and one incline to a depth of 110 feet. A drift over 100 feet long was run southward from the bottom of this shaft. In 1929 the property was bonded to James Kidwell of Portland, Oregon, who was operating the property during the period the field work was being done for this report. Some ore of good grade has been shipped from the Yellow Bird claim where the ore occurs along a fissure in limestone. But the main prospecting at the Ermont mine has been directed toward developing a tonnage of low-grade ore sufficient to justify the construction of a mill.

Andesite porphyry has been intruded into the Ermont limestone in the vicinity of the mine. It tends to follow the bedding planes of the limestone, but in some places clearly cuts across the bedding. Two sill-like bodies of andesite porphyry crop out east of the mine but, as exposed at the surface and in the prospect holes, these appear to join and form a nearly circular southern boundary.

83. Knapp, George, personal communication.

The ore is found in limestone at the contact with the andesite porphyry, which is usually highly altered and may be brown or almost white in color. Next to the ore the limestone is also apt to be stained a brown color and to have a peculiar mottled appearance, which has caused it to be locally termed "zebra limestone". Fracture zones in the vicinity of the mine strike north of east. The limestone in the vicinity of these fractures has been highly silicified and in places carries gold and silver. The ore in the vicinity of the main shaft also is frequently siliceous, though it is more often a soft porous non-siliceous material. Large irregular bodies of a low-grade ore have been prospected near the surface. A sample of the oxidized ore from the lower tunnel assayed 25 oz. in silver and $2.00 in gold per ton. This sample, which was taken by the writer, was higher in silver and lower in gold than the average.

ARGENTA MINING CO. PROPERTY

The Argenta Mining Co. property consists of five patented claims and six unpatented claims. The company was organized in 1928 by Judah Judah of Argenta, G. V. Elder and Ralph Rowlands of Dillon, Montana. The upper tunnel, which intersects an oxidized ore body, is 60 feet long and a winze 55 feet deep has been sunk at the end of this tunnel. A lower level, 100 feet below the upper level, has been driven 180 feet toward the ore body exposed in the upper tunnel but had not reached it in 1930. All of this work has been done on the Sir Walter Scott claim.

The ore occurs at the contact between quartz monzonite and limestone. All the limestone except a small outcrop is covered with the "upper bench gravels" on the surface. The ore is entirely oxidized and consists largely of a soft porous limonite said to carry considerable gold. Bismutite (hydrous basic bismuth carbonate) is found with the oxidized material. Some ore has been shipped.

DEPOSITS ALONG FISSURES AND SHEAR ZONES IN QUARTZITE

The deposits along fissures and sheer zones in quartzite have not accounted for much of the production in the Argenta district. The Carbonate has been the most important mine of this group, but thus far the ore has not been continuous. Deposits of the Groundhog type where quartz and gold have been introduced into brecciated quartzite along a well-defined fault fissure warrant more attention, provided the sampling proves the ore to be of commercial grade.

CARBONATE MINE

The Carbonate mine is in the NW.¼ of sec. 18, and was located by Phil M. Brown in 1890. He shipped about 10 cars to the local smelters and then sold the property to the St. Louis & Montana Co., who sank a shaft to a depth of 75 feet near the south end-line of the Rena claim. The property was relocated by W. M. McMannis and Alfred Graeter, and was finally acquired by A. H. French and George W. French of Argenta, who are the present owners. McMannis and Graeter mined some ore but practically all of the production is credited to Mr. Brown. The main shaft is 90 feet deep and several shallower shafts have been sunk besides the 75-foot shaft sunk by the St. Louis & Montana Co.

The ore is found in a well-defined vein in Flathead quartzite. The vein strikes N. 70° W., and dips 70° S., at the surface but reverses to a northerly dip at 40 feet depth. A grayish-green andesite porphyry dike follows along the hanging-wall of the ore and in one place a segment of the vein is offset 50 feet to the west. The ore occurs in lenses and is broken and associated with gouge. Most of the ore shipped was a dark-gray lead carbonate.

GROUNDHOG MINE

The Groundhog mine is southeast of the Carbonate, in sec. 18. A. H. French and George W. French located the property in 1895, and have shipped one car of ore which assayed $20 per ton in gold. Shallow shafts have been dug along the vein at intervals for over 1,100 feet, and a shaft 100 feet deep has been sunk near the portal of the principal tunnel which is 75 feet long.

The ore occurs in Flathead quartzite along a fault fissure which strikes N. 30° W., and dips 80° N. The quartzite has been brecciated for a width of three feet along the fault, and this brecciated material has been re-cemented with quartz carrying gold and pyrite. The vein is strongly marked by slickensides, and horizontal striations are very well defined.

DEPOSITS ALONG FISSURES IN SHALE

Deposits along fissures in shale have probably produced ore valued at $200,000. They have been the source of a considerable part of the gold production of the district as well as much of the lead and silver. Because of the nature of the wall-rock, most of the underground openings are now caved, and little information can be gained regarding the underground geological conditions. A considerable expenditure would, in most cases, be necessary to recondition the old workings for a development program.

GOLDEN ERA MINE

The Golden Era mine, which is in the NE.¼ of sec. 13, was discovered in 1880, by W. D. Booth. It was afterward re-located by A. I. Watts, but neither locator shipped ore. George W. French and Henry Laughlin bought the property in 1884 and shipped a small tonnage to local smelters. The St. Louis & Montana Mining Co. purchased the mine and shipped considerable ore besides taking out about 1,000 tons of second-class material which was later milled by a Mr. Taylor. The prospect is now owned by the J. F. Imbs estate.

An inclined shaft 300 feet deep is the principal entry into the mine. The shaft starts in thin-bedded quartzite but enters green and red shales at a depth of 10 feet. The shaft is now closed 20 feet below the collar. The ore occurs in a well-defined vein, striking about N. 5° E., and dipping 60° S., at the surface. The shale beds dip at flat angles to the south in the vicinity of the mine. The vein has been stoped to the surface near the shaft and was from one to four feet wide. The best ore consisted principally of galena and pyrite in a quartz gangue and, although water was encountered at a depth of 60 feet, the ore was partly oxidized on the bottom level. Five carloads of the ore had an average metal[84] content of 25 per cent lead, 21.54 oz. silver, and 4.35 oz. gold per ton.

RENA MINE

The Rena mine is in the NW.¼ of sec. 18, and was located by Homer Lawrence and John Miles in 1884. They sank a shaft to a depth of 70 feet and shipped considerable ore to smelters in Omaha, Nebraska. They sold the property to the St. Louis & Montana Mining Co., who sank a shaft to a depth of 300 feet and made a crosscut to the vein. The St. Louis & Montana Co. shipped only a small amount of ore, but lessees later made some shipments. A. H. French acquired the property in 1922. He estimates a production of 250 to 300 tons.

The ore occurred as a shoot 60 feet long in a well-defined vein which is in flat-dipping Spokane beds. Caved stopes indicate that the vein had a strike of about N. 40° W., and a dip of about 60° S., but according to Mr. French[85] the vein turned and dipped to the north near the bottom of the deeper shaft. A fault is said to have terminated the ore shoot on the south. The primary ore minerals include principally pyrite and galena with gold and silver in a

84. From smelter returns given to A. H. French by J. F. Imbs.
85. French, A. H., personal communication.

quartz gangue. Much of the sulphide ore on the dump is in brecciated quartzite, which has been recemented with quartz and sulphide minerals. Very little oxidation was found below water level at 40 feet. Shipments by Mr. French[86] assayed 20 per cent lead and 2.0 oz. in gold per ton, but the oxidized ore shipped by Lawrence and Miles is said to have had an average gold content of about 5 oz. per ton.

MIDNIGHT MINE

The Midnight mine is in the SE.¼ of sec. 13. The mine was located by Robert Wing in the early 'seventies. He sank a shaft to a depth of 60 feet, but made no shipments. H. R. Paddock and Fred Randolph later relocated the property and shipped some ore. A. V. Clark bought the mine and worked it for several years. He shipped considerable ore and then sold to the Monida Trust Co., which still retains the ownership. The property has probably produced[87] 50 cars of ore with a gold, silver and lead value of about $40 per ton.

The principal openings at the Midnight mine consist of five shafts, one 265 feet deep, another 180 feet, one 150 feet, one 80 feet, and a fifth 60 feet deep. The ore in places has been stoped to the surface. Most of the workings are now inaccessible. The vein is in flat-lying Spokane shales and quartzites and strikes N. 40° W., and dips 70° N., at the surface. It varies considerably in width and in some places splits around "horses" of shale. The principal primary ore minerals are galena and pyrite in a quartz gangue. Oxidation has extended downward for a distance of about 200 feet.

GOLDFINCH MINE

The Goldfinch property, which includes five claims, is in the NW.¼ of sec. 24. The original location was made in the late 'eighties by A. V. Clark. He dug a number of surface pits, sank one shaft to a depth of 60 feet and shipped several cars of ore. The property was purchased in 1890 by George W. French and A. H. French, who are the present owners. Since 1890 owners and lessees have worked the mine intermittently. The total production is about 250 tons.

An inclined shaft at the north end of the Dolphin claim is the principal entry into the mine. Stopes have been opened on the north and south sides of the shaft for a distance of 120 feet. The ore is in shoots along a well-defined vein in Spokane shale. A highly altered porphyrytic dike follows along the vein. The dike is irregu-

86, 87. French, A. H., personal communication.

lar in width and the walls are considerably "slickensided". The vein varies from about one to seven feet in width. The ore is in shoots in the vein and is partly oxidized even on the lower level. The primary minerals are principally pyrite and galena in a quartz gangue. Shipments of the ore ran from 0.8 to 1.20 oz. in gold, from 7 to 15 oz. in silver per ton, and about 7 per cent lead.

A tunnel has been run for 200 feet along a shear-zone in Flathead quartzite on the south end of the Dolphin claim. The quartzite is sheared and brecciated for a width of 12 feet. No shipping ore has been encountered in the quartzite.

DEXTER MINE

The Dexter mine is in the NW.¼ of sec. 17. The nearest shipping point, Bond, is on the Oregon Short Line railroad, seven miles to the west. The property consists of six claims and was being operated in 1929 by the Continental Divide Mines Company, under the direction of W. J. Cushing. The old workings are no longer accessible but according to Mr. Cushing[88] the ore was exceptionally high-grade in silver. William Dudley shipped most of the ore in the early 'eighties but considerable work was later done by the St. Louis & Montana Co. Following this very little work was undertaken until 1929, when the Continental Divide Mines Co. started an exploration program.

Several shafts were sunk, one by the St. Louis & Montana Co., to a depth of 317 feet. It is connected with the surface by a tunnel 260 feet long. A crosscut from this tunnel enters the old stopes, now inaccessible. The principal ore deposits were found in veins in shale not far from the contact with granodiorite. Almost the entire length of the tunnel passes through brecciated rocks cut by a number of well-defined fault surfaces. The old stopes are situated to the southwest of the tunnel. Fragments of the ore on the dump are composed mainly of partly oxidized galena, pyrite and tetrahedrite.

Some contact metamorphic deposits in limestone have been explored in the flat northeast of the St. Louis & Montana Co. shaft. The limestone is garnetized and contains much recrystallized calcite. In 1929 the principal operations consisted in sinking the Galena shaft, which is about 2,000 feet southeast of the old mine. The shaft had been sunk to a depth of 60 feet on a vein striking S. 20° E., with a dip of 70° S. The enclosing rock is largely garnetized limestone with granodiorite along the hanging-wall at a depth of 20 feet.

88. Cushing, W. J., personal communication.

The vein had widened from a few inches near the surface to about two feet near the bottom of the shaft. The ore consists mostly of galena, pyrite and some tetrahedrite. It is partly oxidized on the bottom level.

GLADSTONE MINE

The Gladstone and Argenta claims comprise the Gladstone group. They are in the SE.¼ of sec. 13, T. 6 S., R. 11 W., and were located in the late 'eighties, the Gladstone by Mark Bray and the Argenta by James McKay. The Argenta produced 150 tons but the Gladstone has had little or no production. The J. E. Morse estate of Dillon, George W. French of Argenta, and the Amede Bessette estate of Bannack, Montana, own the property.

A shaft 200 feet deep has been sunk on the Argenta and a few drifts were run from it. The principal working on the Gladstone claim is a 50-foot shaft. Neither shaft is now accessible. The vein, which strikes N. 45° W., and dips 80° N., is in the shale and thin-bedded quartzite of the Spokane formation. Much brecciated material cemented with calcite is found on the dumps of the Argenta claim; the vein is said to have entered "clay" near the bottom. The principal value of the ore was in gold, although it carried considerable lead. The ore from the Argenta claim carried $50 per ton in gold, but that in the Gladstone shaft was of much lower grade. A vein five to six feet wide and carrying $12 per ton in gold is said to exist at the bottom of the Gladstone shaft.

ORE SHOOTS ALONG VEINS AND SHEAR ZONES IN QUARTZ MONZONITE

The most recent notable production in the Argenta region has come from the Ferdinand mine, a deposit in quartz monzonite. The ore was of shipping quality and occurred in a good-sized deposit. Prospecting is made difficult at present by the condition of the shaft. Little water was found in the Ferdinand, but water became a serious problem in the lower level of the Jack Rabbit mine.

FERDINAND MINE

The Ferdinand group is in the SE.¼ of sec. 29, and consists of 11 small claims 100 by 200 feet in size. The mine was discovered in 1868 by Thomas Harrison, who shipped some ore to Swansea, Wales; later the Ferdinand ores were treated at local smelters. Mining ceased when the sulphide ores were reached and the property lay idle for 20 years, until the St. Louis & Montana Mining Co. were able to treat the sulphide ore by giving it a preliminary

roast. The mine supplied ore to the Argenta smelters for two years at this period. LaFayette Scott acquired the property from the St. Louis Co., and it was owned by his estate until 1909, when his administrator sold it to the Argenta-Dillon Mining Company. This company opened up the shaft and shipped some ore. In 1925 G. A. Decker and Roy B. Herndon of Dillon secured a lease and stoped ore from the 80-foot level. In 1927-28 Mr. Decker and Harry Renz of Argenta shipped 17 cars from the same ore body. Theodore Nelson, William D. Ross and Martin Sorensen of Dillon now own the Ferdinand.

A shaft 115 feet deep is the principal entry into the mine. One level was opened northwest of the shaft at a depth of 80 feet, and another near the bottom of the shaft. The ore occurs near the contact of quartz monzonite with Mississippian limestone along a shear zone which strikes N. 30° W., and dips 90°. The stopes are now caved in but during the writer's visit to the property in 1927, about 12 feet of ore was exposed in the face of the drift. It was not solid ore but sulphide material alternating with bands of soft, highly altered and partly mineralized quartz monzonite. Part of the material was shipped as it was mined and part of the material was sorted. A carload of the better grade material contained 22.1 per cent lead, 15.5 per cent zinc, 1.18 per cent copper, 6.1 per cent iron, 8.5 oz. silver, and 0.01 oz. gold per ton. A carload of unsorted ore contained 10.4 per cent lead, 12.5 per cent zinc, 0.54 per cent copper, 6.0 per cent iron, 4.1 oz. silver, and 0.01 oz. gold. The principal minerals in the sulphide ore are galena, sphalerite, chalcopyrite and pyrite. Polished sections show the presence of pyrargyrite in small amounts. Chalcopyrite is disseminated through the sphalerite as oriented grains, some less than 1/400 of a millimeter across but with an average diameter of about 1/200 of a millimeter. The ore is only slightly oxidized at a depth of 80 feet. Because of the clay-like nature of the wall-rock next to the ore, considerable difficulty was experienced in preventing caves.

JACK RABBIT MINE

The Jack Rabbit mine, which has the distinction of being the deepest mine in the Argenta district, is in the NW.¼ of sec. 29, about one-half mile northeast of Argenta. It was discovered by J. P. Fletcher in the 'seventies, on a small outcrop of the ore. An inclined shaft was sunk to the 140-foot level. The Conda Mining Company operated the property from 1915 to 1919, and sank a shaft to a depth of 300 feet, besides running 200 feet of crosscuts

on the 200 and 300 levels to the Jack Rabbit and Copper Bell veins. Water was encountered at 90 feet, and at a depth of 300 feet two pumps were used to handle the flow. The shaft is now closed. The Conda Mining Company shipped about 15 cars of ore.[89]

The ore is in quartz monzonite not far from the contact with limestone. The ore from the lower levels consists principally of chalcocite and pyrite in a quartz gangue. The ore shipped by George D. Spafford assayed 16 per cent copper and 32 oz. silver per ton.[90]

COPPER BELL MINE

The Copper Bell claim is half a mile north of Argenta, and west of the Jack Rabbit. It was located in the late 'seventies by J. P. Fletcher, and later relocated by A. J. Shoemacher, who did most of the work on the property. Mr. Shoemacher let the property go by default and it was relocated by Alexander Pilon, who sold it to J. E. Oppenheimer estate and William B. Orem of Butte. The production has been small, probably not over one car.

The Copper Bell vein is opened by a shaft 112 feet deep and has been prospected for a short distance along the strike on three levels, the 45, the 60 and the 112-foot levels. The shaft is now filled to the 60-foot level. The ore occurs along a vein in quartz monzonite near the limestone contact. The vein, which has "slickensided" walls, strikes N. 5° E., and dips about 80° SE. The ore is entirely oxidized on the 60-foot level but is said to be largely sulphides on the lower level. The oxidized ore minerals include cuprite, chrysocolla, malachite, copper pitch, and limonite. One car of ore shipped by Mr. Shoemacher ran 10 per cent copper and carried some silver and gold. Oxidized ore at the surface assays $20 in gold per ton.

BELLA MINE

The Bella mine is on the outskirts of Argenta on the south side of Rattlesnake Creek. It was located by A. H. French in 1906, and was called the Whopper. In 1907, the Argenta Mining Co., of Dillon, sank a shaft to a depth of 200 feet and made a crosscut 20 feet to a vein striking north. The vein was solid sulphide material consisting of pyrite and a little galena and sooty chalcocite. The vein starts in quartz monzonite, but encounters limestone at 50 feet.[91] The outcrop contains cuprite, malachite, tenorite, and limonite. The vein is about three feet wide at the surface, but mineralization extends for several feet on either side of the vein.

89, 90. Spafford, George D., personal communication.
91. French, A. H., personal communication.

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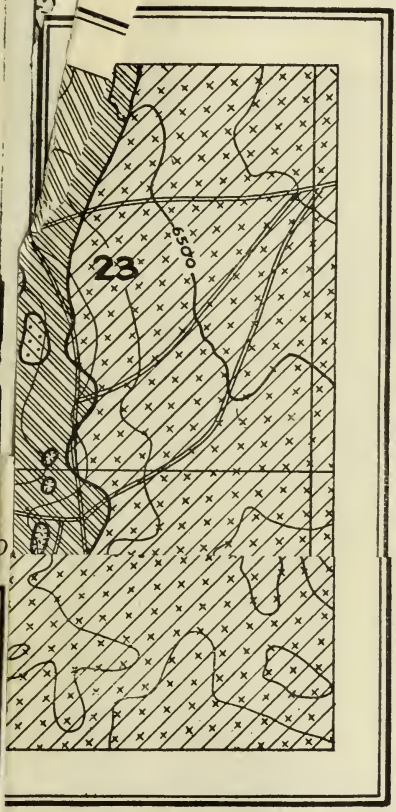

pography & Geology by P.J. Shenon-1925

LEGEND

Sedimentary Rocks

Quaternary

Auriferous Placers

Tertiary

Tg

Gravels

10. Washington
11. Pioneer
12. Charter Oak
13. Ingersoll
14. Lone Star
15. Kent
16. Huron
17. Del Monte
18. Pomeroy
19. Iron Mask
20. Wheal Rose
21. Stevenson
22. New Departure
23. Randall

LEGEND

Sedimentary Rocks

- Auriferous Placers — Quaternary
- Gravels — Tg — Tertiary
- Red Beds — Tr — Triassic(?)
- Quadrant Quartzite — Carboniferous
- Madison Formation — Cm — Carboniferous

Igneous Rocks

- Granodiorite — Kg — Late Cretaceous or Tertiary
- Volcanic Rocks — Late Cretaceous or Tertiary

(8) Mines

LIST OF MINING PROPERTIES

1. Excelsior
2. Wadams
3. Wallace
4. Gold Leaf
5. Priscilla
6. Hendricks
7. Blue Grass
8. Lookout
9. Gold Bug
10. Washington
11. Pioneer
12. Charter Oak
13. Ingersoll
14. Lone Star
15. Kent
16. Huron
17. Del Monte
18. Pomeroy
19. Iron Mask
20. Wheal Rose
21. Stevenson
22. New Departure
23. Randall

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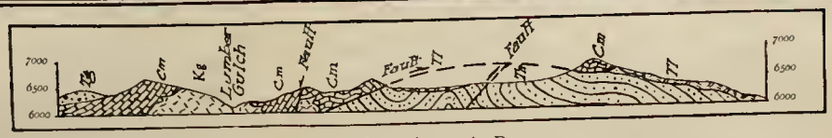
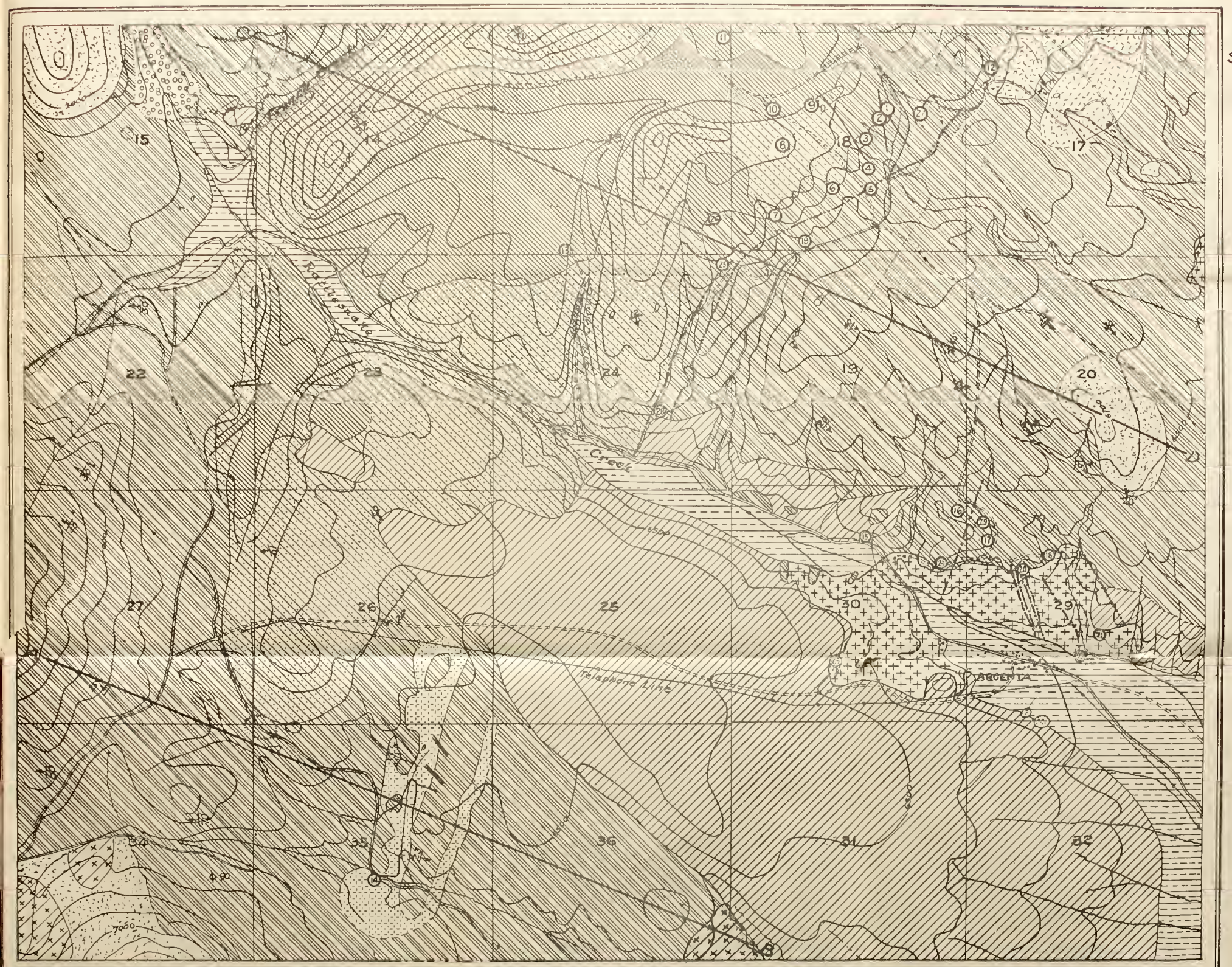


Section A-B

TOPOGRAPHIC AND GEOLOGIC MAP OF THE BANNACK DISTRICT

CONTOUR INTERVAL 100 FEET. SCALE, 1 INCH EQUALS 2500 FEET.

1
2
3
4
5



LEGEND

Sedimentary Rocks

- Glacial Moraine — Quaternary
- Lower Bench Gravels — Quaternary
- Upper Bench Gravels — Quaternary
- Cg — Quadrant Quartzite — Paleozoic
- Paleozoic Limestone (Carboniferous Limestone (Cl), Ermont formation (De), Tilden formation (Et)) — Paleozoic
- Cl — Flathead Quartzite — Paleozoic
- As — Spokane formation — Pre-Cam

Igneous Rocks

- Tl — Volcanic Rocks — Late Cretaceous & Tertiary
- Ka — Andesite Porphyry — Late Cretaceous & Tertiary
- Kgm — Quartz Monzonite — Late Cretaceous & Tertiary
- Kqd — Quartz Diorite — Late Cretaceous & Tertiary
- Sills and Dikes — Late Cretaceous & Tertiary
- Mines

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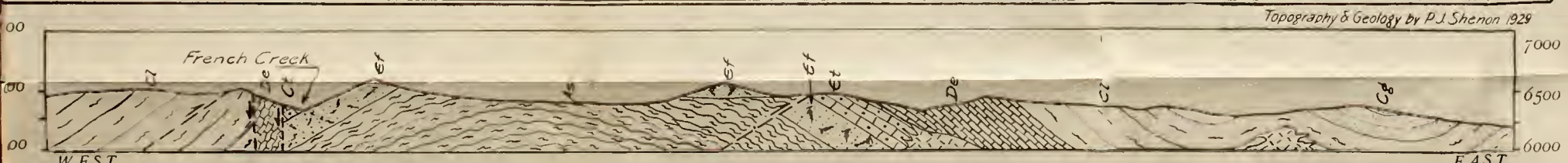

Section C-D

Section A-B

TOPOGRAPHIC AND GEOLOGIC MAP OF THE ARGENTA DISTRICT

CONTOUR INTERVAL 100 FEET SCALE, 1 INCH EQUALS 2000 FEET.

LIST OF MINING PROPERTIES

1. Tuscarora
2. Gov. Tilden
3. Fraction
4. Wooley
5. Coolidge
6. Ground Hog
7. Gladstone
8. Carbonate
9. Joker
10. Rena
11. Golden Era
12. Dexter
13. Gold Finch
14. Ermont
15. Goldsmith
16. Brownell
17. Mauldin
18. Jack Rabbit
19. Stapleton
20. Copper Bell
21. Ferdinand
22. Bella
23. Argenta Mining Co.
24. Iron Mountain
25. Midnight
26. Argenta
27. Polar Bear
28. Legal Tender
29. Anaconda

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by

PHILIP J. SHENON

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